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BORN MARCH 24, 1839. DIED MARCH 18, 1918.

WITH deep regret we record the loss of our old and valued friend George J. Hinde, who for thirty-two years (1886–1918) was an Assistant Editor of the GEOLOGICAL MAGAZINE, to which he has contributed over thirty articles. Dr. Hinde served on the Council of the Geological Society for nineteen years, and was a Vice-President in 1893. He was elected a Fellow of the Royal Society in 1896, held the office of Treasurer to the Palæontographical Society for ten years, and became a Vice-President in 1916. He was awarded the Lyell Medal by the Council of the Geological Society in 1897.

He passed peacefully away at "Ivythorn", Avondale Road, Croydon, March 18, 1918. Dr. Hinde's portrait, his life and scientific work, together with a list of his memoirs, will appear in May.—H. W.

ORIGINAL ARTICLES.

I.—ON THE ORIGIN OF SOME LAND-FORMS IN CAERNARVONSHIRE, NORTH WALES.

By HENRY DEWEY, F.G.S., of the Geological Survey of England and Wales.

(PLATE VII.)

THE present paper deals with some 30 square miles of land situated in Caernarvonshire and embracing the drainage area of the River Ogwen and parts of adjacent river-basins.[1] It is doubtful if any part of Great Britain presents in such a small area so many interesting topographical features and such beautiful and diversified scenery as this part of North Wales. It is in part a thoroughly mountainous region accompanied by characteristics that belong to mountains, and it is a glaciated mountain region with typical glacial topography. But adjoining the mountains is an area of entirely different characteristics, and the change from the one to the other is sudden and complete. An upland plain abruptly terminates against a range of mountains without the interposition of

[1] See One-inch New Series Ordnance Map, Sheet 106.

foot-hills, the crags and pinnacles rising precipitously from the level land; or, in other words, the plain cuts as it were a shelf in the mountainous masses.

Two years ago I communicated to the Geological Society of London a paper on the "Origin of River Gorges in Cornwall and Devon",[1] and therein described an upland plateau that attains a maximum altitude of 430 feet above sea-level. In discussing that paper Mr. E. Greenly and Professor Fearnsides called attention to the existence in North Wales of similar coastal plateaux, but at different heights above sea-level from the one I had described. At the time those comments were made I was under an impression, gained during a short visit to North Wales in the spring of 1915, that a precisely similar feature terminating at the same height above sea-level occurred in both Cornwall and Caernarvonshire. But I was not sufficiently versed in the land-forms of the latter county to feel justified in asserting their practical identity. I therefore resolved to revisit the district to inquire more particularly into these land-forms, and in consequence spent some weeks during the summers of 1916 and 1917 in making a close investigation of the points to be solved. As a natural consequence other problems arose, and one in particular that cannot be settled in Cornwall or Devon, namely, the effects of glacial conditions upon this upland plain and the amount of denudation which has taken place since those conditions terminated. Restricted railway facilities more or less confined work to the district around Bethesda, and in consequence I chose for detailed investigation the valley of the Ogwen and the country lying between Bethesda and Llanberis, and extending westward to Caernarvon and Bangor.

Previous Literature.

This district is classic ground. Darwin[2] recognized the glacial features of parts of it and described in detail the valley of Llyn Idwal. Many years afterwards Sir Andrew Ramsay[3] (in spite of great difficulties, especially with regard to inadequate topographical maps) fully and accurately described the mountainous tract. His work will be referred to frequently, but it may here be said that its accuracy is such that it needs but little revision, except where additions and refinements made possible by more precise methods and the general advance in geological science have necessitated modifications of nomenclature. His inferences, however, are open to question, and have already drawn into controversy many observers, including Watts,[4] Marr and Adie,[5] Dakyns,[6] Jehu,[7] and W. M. Davis.[8]

[1] Quart. Journ. Geol. Soc., vol. lxxii, for 1916, pp. 63–76, published 1917.

[2] Phil. Mag., ser. III, vol. xxi.

[3] *The Old Glaciers of Switzerland and North Wales*, London, 1860.

[4] "Notes on some Tarns near Snowdon": Geol. Mag., 1895, p. 565.

[5] "The Lakes of Snowdon": Geol. Mag., 1898, p. 51.

[6] "Some Snowdon Tarns": Geol. Mag., 1900, p. 58.

[7] "The Lakes of Snowdonia and Eastern Carnarvonshire": Trans. Roy. Soc. Edinburgh, vol. xl, pt. ii, pp. 419–67, 1902.

[8] "Glacial Erosion in North Wales": Quart. Journ. Geol. Soc., vol. lxv, pp. 281–350, 1909.

North Wales was perhaps the first district where the former presence of glaciers was inferred from the characters of its land-forms. Darwin and Ramsay both described examples of such forms near Nant Ffrancon as were then acknowledged to be due to glacial action, namely the moraines, perched blocks, roches moutonnées, lakes, and the general U-shaped sections of the valleys. Since then other land-forms have been recognized as equally significant of glacial agencies, such as arêtes, cirques, gendarmes, valley steps, and hanging valleys. Professor Garwood[1] has described typical instances in the Ticino Valley. Now all these features are preserved in North Wales, but perhaps nowhere in so characteristic a manner as in the Nant Ffrancon district. Further, their relationship to earlier land-forms is equally well revealed in this neighbourhood, and for these reasons the district is one of particular interest to all students of geomorphology.

In the following account each feature is described as it is met with in following the valley from the water-divide downwards to its confluence with the sea.

The Ogwen Valley.

The Afon Ogwen rises on the southern slopes of Carnedd Dafydd as a turbulent mountain torrent, the Afon Dena, and dashes downhill among rocks and boulders in a series of rapids and cascades, pursuing a course roughly parallel with a neighbouring stream that afterwards flows in a diametrically opposite direction. Near Pont Ty-côch the two streams reach flat land partly covered with glacial drift and peat, but beneath these superficial deposits lie solid rock scored deeply with striæ and worn into roches moutonnées. This low ground, although apparently flat, is the water-divide between the Rivers Ogwen and Llugwy, and from whatever point it is viewed appears to be a valley occupied by a sluggish river, which might be flowing in either direction.

The Lakes.

The Ogwen next flows through marshy ground for a distance of three-quarters of a mile, and then swells out into a lake, Llyn Ogwen (Pl. VII, Fig. 1). This sheet of water, nearly a mile in length, is broadest at its eastern end and narrows towards the west, where its waters escape through a gorge. The total area covered by it is approximately 456,400 square yards, but in spite of its size the lake is remarkable for its extreme shallowness, the water nowhere attaining a greater depth than 10 feet. It is also noteworthy that it is deeper at the eastern end than at the west, the gradient of the lake-bottom sloping towards the east.[2] It is a picturesque lake, surrounded as it is by noble mountains (Pl. VII, Fig. 1) that form the highest group in North Wales, and is apparently landlocked. On its northern banks rise the crags of Carnedd Dafydd, with a perfect cwm facing east near its summit, and in which lies the small lake

[1] "Features of Alpine Scenery due to Glacial Protection": *Geographical Journal*, 1910, pp. 310–39.

[2] Jehu, op. cit., p. 440.

Ffynnon Lloer, from which a small stream, the Afon Lloer, flows down to Llyn Ogwen. To the south it is flanked by a series of magnificent precipices terminated by the serrated edges of Tryfaen and Glyder Fâch. There are many fine cwms along this ridge, all facing north-east, and in one lies Llyn Bochlwyd.

The lower slopes of Tryfaen and Carnedd Dafydd both bear record of the thickness of the former ice-sheet in their roches moutonnées and striæ which extend far up their slopes, and also to the action of frost and ice in their cwms, llyns, and moraines, but all these features are still more perfectly preserved at the western end of Llyn Ogwen.

The Holyhead road follows the side of the lake for a distance of over a mile and at approximately the same level the whole way, namely, a thousand feet above the level of the sea. A spur of Carnedd Dafydd bounds the western end of the lake and is rounded into smooth mammillations and roches moutonnées. It is seen in Pl. VII, Fig. 1. The waters of the lake, however, flow across this smooth rock-barrier in a low gorge and then suddenly plunge down into a deep chasm. This feature will be described later in relation to a similar one connected with it.

Llyn Ogwen lies on an upland plain; arising steeply from this plain is a rock-step, deeply scored with glacial striæ, through which a mountain torrent, the Afon Idwal, has ripped a gorge; if this torrent be followed, a second plateau is soon reached. It spreads out in front of a ring of magnificent precipices that form the base of Glyder Fawr and Y Garn and embrace the gloomy Llyn Idwal. This plateau rests at a height of about 1,250 feet above sea-level and is largely covered with strewn blocks derived from the almost vertical walls of the precipices, and in part arranged as moraines. Ramsay notes that moraines now skirt Llyn Idwal, the progressive retreat of the glacier being marked on the western side of the lake by four moraines arranged concentrically one within another. On the south and on the east of the lake there are patches of moraine matter, and other moraines dam back the waters at its northern end. Other glacial features, such as blocs perchés, roches moutonnées, and glacial striæ, are conspicuous, the striæ all being directed towards Nant Ffrancon.

Professor Jehu[1] investigated the lake and its surroundings, and notes that it is broadest at its lower end, whence the River Idwal issues. The length of the lake is 846 yards, maximum width 340 yards, area of water 159,300 square yards, mean breadth 188 yards or 22 per cent of its length. He took eighty-one soundings, which prove the bottom to be very irregular, in places muddy; but over a large part boulders of all sizes seemed to be scattered about and interfered with the soundings. The greatest depth registered was 36 feet in two places, the mean depth was 11 feet, while the greater part of the lake was found to be extremely shallow, 57 per cent of the total area corresponding to depths under 10 feet. The deepest part of the lake lies close to its western shore. Professor Jehu considers that Llyn Idwal was probably at one time

[1] Op. cit.

much deeper, but is gradually filling up by rock-falls from the neighbouring heights. A mass of drift crosses the valley at the foot of the lake, and seems to be of sufficient depth to account for its formation and disposes of the necessity for supposing it to be a rock-basin. The configuration of the lake-bottom supports this view, for there is no deep cup-shaped depression such as is found in other lakes of North Wales, but an irregular floor with rocky knobs jutting up here and there. Professor Jehu therefore concludes that the lake is a barrier-basin with a floor that may have been modified by glacial action.

The Valley-Steps at Rhaiadr Ogwen.

Llyn Ogwen lies on a plain at 1,000 feet above sea-level. Llyn Idwal lies on a plain at 1,250 feet above sea-level, while Nant Ffrancon extends as a long wide flat for a distance of 3 miles at a nearly uniform height of 700 feet above the level of the sea. There are thus three plains, rising one above another in tiers; the rise, however, between each is not gradual, but abrupt. These features are shown on the profile section, p. 150 (Fig. 1*a*), drawn to natural scale, and in the view of Nant Ffrancon (Pl. VII, Fig. 2), where the lower valley-step is seen across the top of the valley.

Between Llyn Idwal and Llyn Ogwen the step is steep, and the river rushes down its face as a series of torrents, in places in shallow gorges until it unites with the River Ogwen at Pont Pen-y-Benglog to form the cascade known as Rhaiadr Ogwen. A fine view of the chasm is obtained from near the bridge. After heavy rain the gorge is choked with spray and the "monotonous roar that fills the ravine".

Various hypotheses have been advanced to account for the origin of such "valley-steps" in glaciated countries. The two steps at Rhaiadr Ogwen are certainly, in part at least, due to the harder interbedded and intrusive igneous rocks that lie among the sediments, and the absence of similar steps in Nant Ffrancon may be due to the absence of igneous rocks in the rest of the valley.

The gorges cut by the Rivers Idwal and Ogwen at Rhaiadr Ogwen have carried the drainage of the two upland plains into Nant Ffrancon; but the study of the topography of the locality indicates an earlier drainage into the River Llugwy. This was suggested by Brend, and the bathymetrical survey of Professor Jehu at Llyn Ogwen lends support to the hypothesis in that it proved the floor of the lake to fall from west to east, i.e. in a direction opposite to the flow of the water of the lake. This diversion of drainage was brought about in glacial times when glaciers filled Cwm Idwal and the plain at Llyn Ogwen. Sub-glacial streams then cut shallow gorges in the valley, and these streams persisted when the ice melted and carried off the drainage of the two upland plains into Nant Ffrancon.

Post-Glacial Erosion.

The gorges thus initiated have since been deepened by the cascades at Rhaiadr Ogwen. Similarly, on the west of the valley a small mountain torrent has ripped out a beautiful gorge near Blaen-y-nant Farm; it is cut in bedded ash and is upwards of 40 feet deep. At

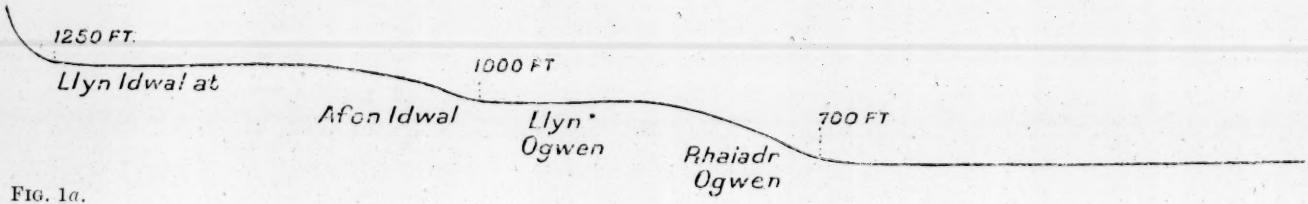


FIG. 1*a*.

Profile of the Ogwen Valley from Llyn Idwal to Pentre. *Scale - 6 inches to one mile.*

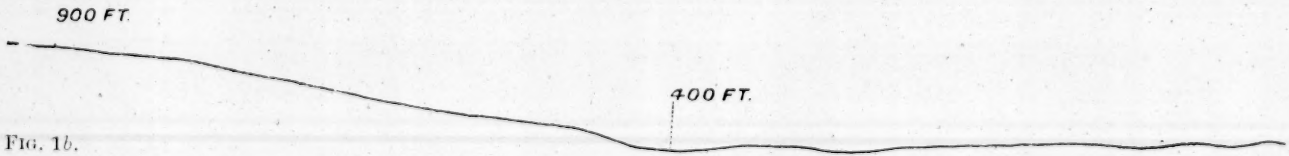


FIG. 1*b*.

Profile of surface from Graig-lwyd through Tregarth to near Gelli. Scale - 6 inches to one mile.

FIG. 1.—(*a*) Profile of the surface of the land between Llyn Idwal and Nant Ffrancon, showing the two valley-steps. The descent from Llyn Idwal to Llyn Ogwen is 250 feet; the river forming a series of cascades and rapids. The second step is deeply incised by a gorge where Rhaiadr Ogwen plunges down to Nant Ffrancon. (*b*) Profile of the surface of the "Pliocene" plain between Graig-lwyd and Gelli. The abrupt change of slope occurs just above the 400 ft. contour-line and marks an ancient cliff line.

Rhaiadr Ogwen the gorge is not much deeper, and the amount of post-Glacial cutting appears to be about 50 feet. Elsewhere in the valley there is no evidence of a greater amount of post-Glacial fluviatile incision, but another significant instance of a similar nature is the gorge by the Salmon Pool near Pont-y-garreg. Here the thick-bedded grits of the Lingula Flags are carried across the valley as a barrier through which the Ogwen has cut a gorge with vertical walls not 25 feet apart. At the same locality there are three prominent terraces preserved, each about 30 feet above the other and all smoothed and striated by ice. These were overwhelmed by the great glacier; but as this retreated up-valley the barrier must have held back the waters that formerly spread out as a lake and filled Nant Ffrancon (Pl. VII, Fig. 2). Subsequent erosion has brought the base-level below that of the wide level tract of Nant Ffrancon, and the Ogwen now rushes in a series of picturesque cascades and torrents through this belt of country where the grits occur. These grits strike straight across the valley and sweep upwards to the west to form the precipices rising above Cwm Graianog. They are intensely hard and coarse-grained rocks, and under the microscope are seen to consist of rounded grains of quartz with a subordinate amount of fresh plagioclase felspar and some scales of white mica. The rock might be termed an arkose.

A similar amount of post-Glacial erosion is indicated at many localities over a wider area, especially in that little visited and desolate tract of moorland that lies between the ridge forming Carnedd Dafydd and Carnedd Llewellyn and the mountains near Aber. In this tract the rivers have here and there removed the glacial detritus from their valleys, but the depth of the post-Glacial valleys is seldom more than 45–50 feet. But the Afon Anafon near Aber has cut a deep trough in debris and has led to a local collapse of a huge scree below the mountain, while the great cliff that remains appears to be a contradiction to the other evidence.

Here, however, the effect of recent local denudation may be noticed. In Cwm Cŏch near Blaen-y-nant Farm an enormous gash has been rent through scree material by a cloud-burst. It is upwards of 20 feet deep. Greenly[1] describes the effect of a similar cloud-burst on the scree beneath the lower slopes of Carnedd Dafydd where the road was swept away by the torrential waters.

The mode of occurrence of the glacial drift leaves little room for doubt that the principal topographical features had been formed before the coming of the ice. All the valleys examined indicate that they are essentially pre-Glacial and that very little modification of them has taken place in post-Glacial times. This subject will be reverted to later and some evidence given in support of the views expressed. In the meanwhile the glacial characteristics of the Ogwen valley will be further considered.

The Cwms and the Hanging Valleys.

On the western side of Nant Ffrancon there are many typical cwms, and it is significant that all of them face either to the east

[1] Geol. Mag., 1901, pp. 68, 69.

or to the north-east (Pl. VII, Fig. 2). First is Cwm Bochlwyd, lying between spurs thrown out from Glyder Fâch and Glyder Fawr, and in which lie the sombre waters of Llyn Bochlwyd; this forms a characteristic hanging valley with a mountain torrent ripping its course down to Llyn Ogwen. Next comes Llyn Idwal in Cwm Idwal, flanked by the grand precipices of Glyder Fawr and Y Garn. Then from south to north follow Cwm-clyd, Cwm Cywion, Cwm-gôch, Cwm-Bual, Cwm Perfedd, Cwm-graianog, and Cwm Ceunant. In most of these cwms there are relics of their own small glaciers, especially well seen in Cwm-graianog, and it is significant that the change of slope marking the truncation of the spurs is practically always at a height above sea-level of 1,250 feet; and further, this altitude marks the limit of glacial striæ incised by the great glacier. Of Cwm-graianog Ramsay remarks: "But in none of the tributary valleys north of Llyn Idwal are the signs of a small glacier so distinct as in Cwm-graianog below the steep slopes of Moel Perfedd. It is a small craggy valley over half a mile in length looking across Nant Ffrancon. On the east the felspathic porphyry of Moel Perfedd rises in a rough peak, and on the west the great bare ripple-marked strata of the Lingula grits dip towards the hollow at an angle of 48° or 50°.

"At the mouth of the valley above the steeper descent to Nant Ffrancon, a small but beautifully symmetrical terminal moraine crosses the valley in a crescent-shaped curve, that once passed from 200 to 300 yards up the eastern side of the glacier. On this side almost every stone of the moraine is a fragment of the felspathic rock of Moel Perfedd, having been shed from the edge of the glacier by a part of the ice that had that mountain as its source. Further west along the moraine, the material becomes mixed with fragments of grit and slaty sandstone, and, by degrees, passing to the western side of the valley, the moraine matter consists entirely of pieces of the Lingula beds that form the crags of Carnedd-y-filiast. . . . In Cwm-graianog the whole is formed of large angular loose stones mixed with smaller debris. The largest of these lies on the top of the moraine, from 450 to 500 feet above Nant Ffrancon. It was originally 11 yards long, 9 broad, and about 1½ high, and when entire must have weighed nearly 300 tons. . . . Inside the moraine the bottom of the valley is covered with glacial rubbish and heaps of loose blocks."[1]

In marked contrast with these cwms is the even unbroken slope that bounds the eastern side of Nant Ffrancon and forms the ridge known as Pen-yr-Oleu-wen. But striæ can be seen on the rocks below Braich-du at a similar height to those on the opposite side of the valley. These facts afford evidence of the maximum thickness of the glacier that filled Nant Ffrancon. The present level of the alluvial tract is 700 feet above sea-level, but the valley is partly filled up with boulder-clay and peat, possibly together 40 feet thick. The ice was therefore certainly not less than 700 feet thick. It enveloped all the land lying at altitudes lower than 1,250 feet, for no

[1] Op. cit., pp. 83, 84.

arêtes or cribs occur below that level, although they commence immediately above.

These cwms are shown in Pl. VII, Fig. 2, and their bases are all very closely at the same altitude. This also corresponds with a plateau feature above Bethesda and lying between Nant Ffrancon and Clegyr. It is marked on the old map as a Turbary plain, but a lake used as a reservoir now occupies most of the area formerly filled with peat. This broad moor is covered with drift and extends into the valley of Marchlyn-mawr, while remnants of it are seen on the opposite side of the Ogwen Valley near Afon Berthan, the Llafar, and Afon Caseg Valleys. The feature is conspicuous at Moel Rhiwen and near Douglas Hill.

In Nant Ffrancon the foothills of the mountains are deeply striated, the striæ pointing down stream; but these do not extend above the level of the lips of the cwms.

Now all these features are attributed by the two schools of glacialists respectively to the protective or the erosive function of glaciers. The views, however, held by the one school are not entirely contradictory to those of the other, but rather are supplementary, i.e. those who ascribe to glaciers a protective function do not exclude thereby erosive action of ice nor the backward stoping of Bergschrund.

Thus Garwood admits the power of ice to erode, but also insists on its efficacy under certain circumstances to act much as a bed of clay would in protecting underlying rock from disintegration due to the expansion and contraction of freezing water. In cwms the gently sloping valley heads are thus protected, while the higher slopes are exposed to sun-heat and frost, especially in such cases where the main glacier has retreated up its valley leaving tributaries above the ice-line, in cwms receiving only small amounts of sun-heat on account of their north-easterly or easterly prospect. The almost invariable rule of the cwms facing these and the absence of cwms facing other directions strongly supports Garwood's contention.

The Lower Valley of the Ogwen.

Between Bethesda and Bangor the Ogwen flows rapidly through a deep and well-defined valley, which everywhere bears record of glacial activity. The strongly moutonnéed rocks and deeply incised striæ are well preserved on the Bethesda slates near the village and at the mouth of Nant Ffrancon, and at first the wide valley appears to be free from drift deposits. Closer examination, however, proves that this supposition is incorrect. To take two or three instances only among many others, there is first the pit near Felin hen Station, where upwards of 20 feet of boulder beds are exposed in a low hill-side rising gently from a plain; while near the Halfway House the lower slopes of a hill have been cut into, and the open pit exposes more than 30 feet of similar boulder material. Elsewhere in the area described low hills rising above the general plain level are seen to consist of boulder-clay or sand, and these occur at various heights above sea-level and down to and below low-tide mark, as near Penrhyn Castle and at Beaumaris on Anglesey. Old valleys are partially

infilled with glacial deposits, and the plain and even the tops of hills carry boulder beds. This evidence clearly indicates that the wide general topography as it at present exists was for the most part produced in pre-Glacial times, or at least when the spreads of glacial detritus were laid down.

The 430 foot Plain.

By keeping to the Ogwen Valley, however, a wrong impression of the topography of Caernarvonshire is gained, and it comes as a surprise to find, after climbing the hills, not a mountain region, but a widespread area of gently undulating ground, p. 150 (Fig. 1*b*), where the hills are truncated into flat-topped ridges. On turning towards the mountains it is further seen that this plain abuts against their masses at an even level for many miles, while they rise from it like islands from the sea.

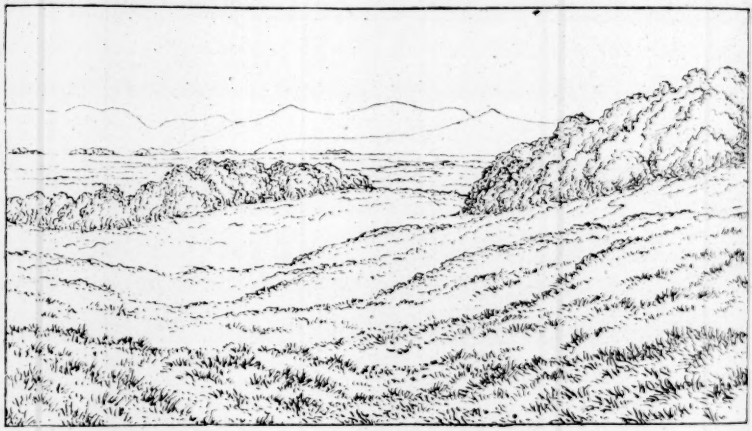


Fig. 2.—The "Pliocene" plateau near Bangor. The plain terminates at a height of 430 feet above sea-level, the mountains near Snowdon rising abruptly from it. Its wide expanse is clearly seen in this sketch.

The above picture (Fig. 2) shows a view of these features taken from the Bangor Golf Links and looking towards Nant Ffrancon, where the wall-like mass of Glyder Fawr is seen bounding the valley at right angles to it.

Another sketch (Pl. VII, Fig. 3), made near the Anglesey Monument, shows similar features of a country diversified into a series of parallel ridges with flat tops, terminating against the mountain mass. In the area bounded by the Ogwen Valley, the Padarn Valley, and the mountains there is scarcely a hill that rises above this plain, although much of the ground is lower and there are several deep river-valleys. The amount of erosion that has taken place since the uplift of the plateau is marked by the Menai Straits, which attain a depth of 70 feet below sea-level, while the Afon

Cegin, the Afon Seiont, and the Afon Cadnant have each cut valleys several hundreds of feet deep in the plateau.

Some agency has truncated all the land at a common level, and inspection of the Ordnance map shows that level to be 430 feet above that of the sea. There are, however, a few hills that rise above this plain, and on almost every one of them a hill-fort consisting of circular earthworks is preserved. To mention some examples, there are the two camps situated respectively on the west and the east of the Padarn Valley near Cwm-y-glo; the fine hill-fort at Pen-y-ddinas by Llanddeiniolen, the Castell near Rhiwlas, the Camp by Tregarth, and another at Rhiw Gôch. Similarly on Anglesey [1] the earthworks are placed on the few hills that rise above 400 feet and are there described as various Mynydds.

But this plain does not extend far to the east of the River Ogwen, as the mountains run out to the coastline near Aber. Its margin is rendered obvious on the map by the crowding together of the contour-lines above 400 feet, but it is still more conspicuous in Nature. Fig. 1*b*, p. 150, is drawn to the natural scale, and shows the abrupt change of slope at the base of the mountains.

It is difficult to follow the edge of the plain across country, because there is no road running parallel with it, but the feature is distinctly seen even from a distance. Nevertheless, when the margin is reached the ground is usually boggy and often covered with saturated peat, with small streams soaking through it. Tregarth village is built in part on the plain, and here the rise to the adjacent mountain is marked by several boggy meadows. But perhaps the feature is best seen in the country lying between Llanddeiniolen and Moel Rhiwen, especially near Waen, where hillocks composed of boulder beds rise above the general plain to form dry patches of arable land in a region generally wet.

The feature cuts straight across the mouth of the Llanberis Valley and does not run up into that valley, a fact that implies the formation of the valley subsequently to that of the plain. It then extends in a general south-westerly direction near Llanrug, where Garth is situated on an isolated hill rising out of the plain. Thence by Groeslon and Pen-y-groes it spreads toward the Lleyn Peninsula, but I have not traced it in detail much beyond the valley of the Seiont.

Such a sudden change of topography suggests a different degree of hardness of the rocks underlying the two areas, but reference to the geological map (Sheet 78) shows that in both areas similar rocks occur. These consist of slates, grits, limestones, and shales with bedded and intrusive igneous rocks. In the one area all of them have been planed down to a common level; in the other differential hardness has led to variety of sculpture.

Of late it has been the fashion to adopt American terminology in describing upland plateaux and also to reject the sea as the agent which has produced these features. In some cases the term "peneplain" may be applicable, but it is difficult to imagine why subaerial agencies should cease operating along a purely arbitrary

[1] See Mr. Greenly's forthcoming Memoir on Anglesey (Mem. Geol. Surv.).

line, leaving parts of a district immune from attack and reducing at the same time adjacent areas of similar geological formation and structure to a featureless plain. In the present instance I reject the hypothesis of subaerial erosion. Marine erosion proves its capability of levelling rocks of all degrees of hardness, as anyone familiar with coasts bounding the Atlantic must acknowledge. The Cornish coast is a convincing instance of the sea's power to produce level tracts, and moreover lands of all degrees of hardness ultimately yield and become reduced to the limit of erosion. Such a marine plain is seen at low-water spring tides near Bude, where a quarter of a mile of bevelled rocks are exposed. They consist of alternate beds of hard sandstone and slate, but all have been planed down to a uniform level, or rather a long gentle slope towards the deeper waters. The tide in rising suddenly covers this plain, and is apt to cut the unwary off from retreat. On this coast it is always well to remember that—

> Far back through creeks and inlets making
> Comes silent, flooding in the main.

There can therefore be no valid reason to offer why the sea did not similarly operate on this plain in North Wales.

It is more difficult to determine the period when this reduction occurred; the fact that the feature terminates in both Cornwall and in North Wales at precisely the same height above sea-level suggests that the two plains are contemporary, whatever their geological age may be. That in North Wales the plain is pre-Glacial is proved; in Cornwall there are strong reasons for supposing it to be of Pliocene age. We are then perhaps justified in accepting as of the same age the North Welsh plain at this level.

In both districts, however, there are wide tracts at lower levels,[1] notably that at 200–300 feet above Ordnance Datum, but in both these do not occur above 430 feet, with the exception of those already mentioned at 700, 1,000, and 1,250 feet respectively. The lower plains may also represent other marine plains or peneplains, but with these I am not concerned. The point to be emphasized is the occurrence in both districts of a plain which does not rise higher than 430 feet above sea-level.

Before concluding I wish to express my thanks to Mr. Greenly for his kindly advice and suggestions made during the writing of this paper.

Conclusions.

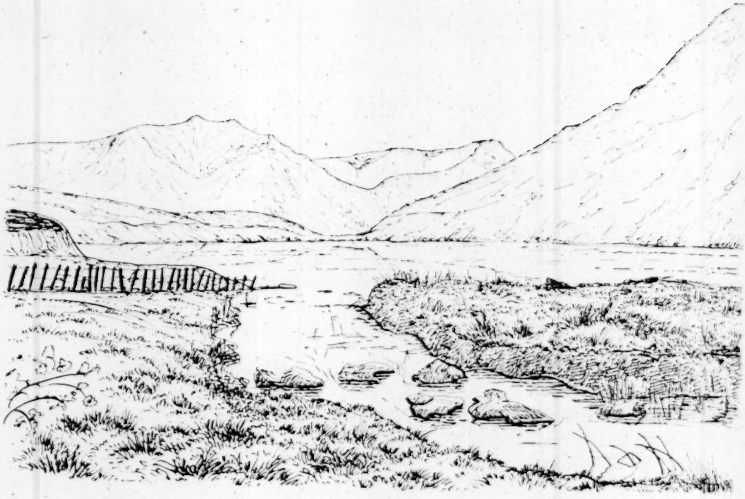
1. Glacial phenomena as expressed in land-forms have long been known in North Wales. In the valley of the Ogwen the whole series of land-forms characteristic of glacial topography are represented, namely, the lakes, cwms, hanging valleys, valley-steps, and arêtes; and in addition the evidence of former glaciers as represented by moraines, roches moutonnées, and blocs perchées.

2. There is sufficient evidence to show that the major land-forms are pre-Glacial and that post-Glacial erosion is comparatively slight.

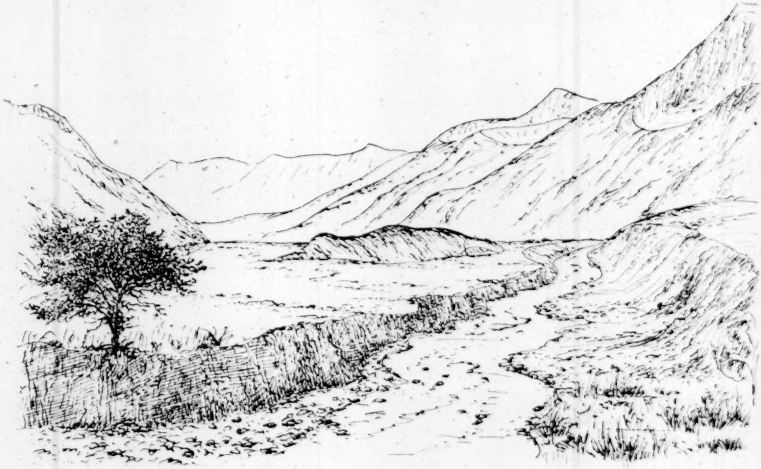
3. Pre-Glacial erosion had sculptured a former upland plain into

[1] See Ramsay, *Geology of North Wales* (Mem. Geol. Surv.), p. 269; also Quart. Journ. Geol. Soc., 1876, p. 116; also Greenly, Rep. Brit. Assoc. Bradford, 1900, p. 737.

1



2



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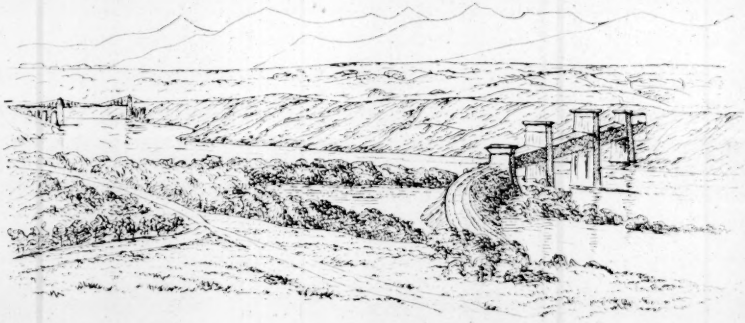


Henry Dewey, del. *Bale & Sons.*

LAND-FORMS CARNARVONSHIRE.

a region diversified with ridges and valleys, with its own drainage system independent of a mountain drainage system adjoining it.

4. This upland plain terminates at a height of 430 feet above sea-level and is of widespread occurrence.

5. A similar plain forms conspicuous features in Cornwall and in Devon, and terminates in those two counties at precisely the same height as that of North Wales. This plain is not more recent than Pliocene, but may be older.

6. There is evidence that these upland plains of North Wales and Cornwall and Devon were formed contemporaneously and by marine erosion.

EXPLANATION OF PLATE VII.

FIG. 1.—Llyn Ogwen. The view shows the landlocked waters of the lake with the amphitheatre of great mountains encircling it. In the middle distance is the low barrier through which the waters escape in a gorge. It is deeply grooved by glacial striæ, which also extend up the lower spurs of Carnedd Dafydd to the right. On the left of the barrier rises a valley-step that separates Llyn Idwal and its plain from Llyn Ogwen. The mountains in the background are Y Garn and Foel Gôch. On both of these mountains are characteristic cwms, all facing to the north-east.

FIG. 2.—Nant Ffrancon, looking south. The valley-step is seen across the head of the valley, over which the waters of Rhaiadr Ogwen fall. In the middle distance is a "roche moutonnée"; on the right are cwms and arêtes, while the lower slopes of the mountain show truncated spurs. The foreground consists of glacial detritus and peat which has accumulated on the floor of the valley. The mountains in the distance are Y Glyder Fach and Y Glyder Fawr; on the right are Y Garn and Foel Gôch.

FIG. 3.—The "Pliocene" plain of North Caernarvonshire. This view is taken from Anglesey and shows the extensive upland plain diversified with deep valleys and flat-topped hills. In the foreground lies the Menai Straits, here about 70 feet deep. The Snowdon range of mountains forming the background rise abruptly from the plain.

II.—The Origin of the Clays and Boulder-clays, Federated Malay States.[1]

By Lieutenant J. B. Scrivenor, M.A., F.G.S.

SINCE the earlier edition on the geology of Kinta was written much fresh evidence has been brought to light on the subject of the origin of the clays and boulder-clays and the tin-bearing deposits showing bedding at Gopeng. The effect of this evidence has not

[1] The subjoined note which accompanied this article from the author to the Editor of the Geological Magazine was received on January 8, 1918, when Mr. Scrivenor was leaving for France:—

Sir,—With reference to Mr. W. R. Jones's paper in No. 287 of the Quarterly Journal of the Geological Society, pp. 165–94 (*issued* November 23, 1917), on the "Secondary Stanniferous Deposits of the Kinta District", I shall be grateful if you will publish the following article on the "Origin of the Clays and Boulder-clays". This was written before I left the Malay States and before I had seen Mr. Jones's paper. I note that on p. 176 of his paper the latter says that at Kacha, Tambun, Lahat, and Papan, clays and boulder-clays can be traced into partly decomposed phyllites exhibiting distinct foliation. I do not remember Mr. Jones offering to show me these occurrences. The section at Siputeh mentioned in the fourth paragraph of p. 177 is that described by myself, and I took Mr. Jones to the mine to see it.

J. B. Scrivenor.

R.E. Depot, Baldock, Herts. *January 7, 1918.*

been to lessen the objections to the glacial hypothesis put forward by myself, but at the same time it still remains the only explanation that meets the facts in a way that can be called at all satisfactory. It may be that long acquaintance with the subject has made me see difficulties in the way of other explanations where in fact no difficulties exist, and my position regarding the question is somewhat akin to that of a doctor versed in tropical medicine who once informed me that the result of many years study of the etiology of *beri-beri* was that he felt he could raise fatal objections to any theory that had been proposed. I have not seen sufficient reason as yet, however, to change my views on the subject of these clays and boulder-clays. Certain sections to be noted later militate against a glacial origin, but the evidence of these deposits, including those showing bedding at Gopeng, being older than the granite of the Main Range is stronger than it was before. In the following paragraphs I will attempt to give briefly a statement of the points for and against all possible explanations of the peculiarities observed in these important sources of tin-ore.

It will be convenient to consider first the deposits that show no bedding. These occur both on the west and on the east of the Kinta River, and are especially well developed in the vicinity of Siputeh and Pusing. The problem regarding them may be stated thus: Are they the result of bedded rocks being broken up and completely disorganized owing to the limestone underneath them being dissolved away and so producing a general sinking movement in the overlying material; or were they originally laid down as unbedded clays with irregularly distributed boulders?

When work was commenced in Kinta the former of these two explanations commended itself, and I think that anyone examining the evidence cursorily would come to the same conclusion. In a paper on the tourmaline-corundum rocks of Kinta (Quart. Journ. Geol. Soc., lxxvi, p. 448, 1910) I gave as my opinion that they were derived from rocks associated with schists over limestone, probably chert and silicified limestone, and I may also remark in passing that on p. 438 I referred to the corundum found in the "alluvium" at Pulai and elsewhere.

At that time, however, it was thought that there were two occurrences of these rocks known to be in situ, i.e. in the position where they were originally deposited before alteration, but in one case mining operations proved this not to be the case, while in the other the mass of rock, close to the Siputeh bridle-path from Batu Gajah, might have been a huge boulder. It is now completely hidden by mining silt.

Bedding that is a division of a mass of rock into clearly defined strata of more or less different composition has never been seen in these clays, but in a few cases a faint trace of lamination has been seen. This, however, might be the effect of pressure on unstratified clay. The tourmaline-corundum rocks are hard, the clays are soft. What is required to prove that the former are derived from a continuous bed or beds intercalated among softer beds is a section showing some sign of it, and as yet no such section has been found.

Another possible suggestion regarding these boulders is that they are analogous to "core-boulders" of granite; that they are portions of beds rich in corundum and tourmaline that have resisted weathering. It is known that the containing clay is sometimes very rich in soluble alumina, derived, it is believed, from minute pieces of tourmaline-corundum rock by the alteration of the corundum, but where clearly bedded rocks are exposed, as at Kacha, Redhills, and near Batu Gajah, there is, with one exception, no trace of the peculiar structure of these rocks. That exception is a rock found near Redhills, containing traces of Radiolaria which may have been the foundation of some of the bodies in the tourmaline-corundum rocks.

It is felt now that the previously held views regarding the origin of these rocks will not meet all the facts, and the objections are well exemplified at Redhills and Kacha. On the Redhills and Pusing Lama mines large boulders of tourmaline-corundum rock are found in tin-bearing clay.

At Redhills limestone was found underneath the clay. On both mines, but on higher ground, soft, weathered, bedded rocks are found. On Pusing Lama a section was once uncovered, showing small tin-veins in tourmalinized shales. If the clay with boulders of tourmaline-corundum rock is simply the shale disorganized over sinking limestone, then the shales should contain the tourmaline-corundum rock too, but, as far as I am aware, they do not. Over the clay these boulders are numerous, but over the shales they are replaced by masses of ironstone formed at and near the surface (Malayan "laterite"). Here, then, is what seems to be a fatal objection to the clay being disorganized shale.

At Kacha the evidence on the old mine worked formerly by Towkay Ong Siew is somewhat different. On the lower part of the mine there are clearly bedded and somewhat sandy rocks with intrusions of aplite. Some of the hardest material has been examined, and nothing was found of the structure of the tourmaline-corundum rocks. On the other hand, on the high ground that has been extensively worked by ground-sluicing, there are abundant tourmaline-corundum boulders, some of which can be seen in situ, and no bedding is to be seen now. If the bedded rocks on the lower level retain their bedding, and if the rocks on the higher level were once bedded, surely the conditions there are more favourable for the preservation of that bedding, seeing that the strata on the top of the hill are less likely to be disorganized by sinking over limestone as it dissolves away than those at the base.

Once on Pusing Lama a thin bed of clay with boulders was seen under shales, and at Kacha evidence was seen of alternation of shale and clay with boulders, but as these sections cannot be seen now they can hardly be cited as evidence.

Another strong objection to the theory of the clay being disorganized shale is its condition at the junction with granitic rocks.

On the Pusing Lama mine a lode was discovered that became well known. It was at the contact of a soft granitic rock and soft clay with boulders of tourmaline rock and powdery tourmaline evidently

of a secondary nature. Tourmaline-corundum rock occurred near by. The earlier work on this lode was underground, but now there is an open-cast mine on the junction. On the one hand is a granitic mass rich in kaolin and traversed by tourmaline veins, one sufficiently well preserved to show a small fault; on the other, deep-red clay in which an apophysis of granitic vein-material was once seen, itself traversed by tourmaline veins. One may argue that away from the junction bedded shales and harder rocks might be disorganized over limestone so as to simulate boulder-clay, but at the granite junction, where the granitic rock is equally soft and contains clearly defined tourmaline veins, the bedding of soft and hard rocks ought to be preserved. But it is not preserved, and the inference is that it never existed.

But away from the junction also there has been evidence against the clay being disorganized shale. At least one vein of ore has been worked open-cast with a course that could be easily followed. How could this be preserved if the clay and boulders are broken-up hard and soft strata?

Even more striking is the evidence at Tekka and Gopeng, where there are good exposures of the junction between granitic rocks on the edge of the Main Range mass and clay at Tekka, while on the Ulu Gopeng portion of Gopeng Consolidated is a junction with schists.

These schists are exposed on old workings at the top of a steep hill overlooking the town of Gopeng. They are clearly bedded and dip at a very high angle to the west. Sandy phyllites are common; tourmaline-schist and actinolite-schist occur. Both brown and white mica occur. The soil above them contains ferruginous masses showing the structure of the schists they have replaced on weathering. Quartz veins are abundant.

The clay at the junction with the granite on the Tekka Ltd. mine and on mines further to the south should, if it is the result of the extreme weathering of schists, still show some resemblance to the Ulu Gopeng sections. The clay cannot be schist that has become a disorganized mass through movement because at the junction tourmaline veins have been traced into it; and moreover there are other veins found sometimes parallel among themselves, but sometimes brecciated by movement, which are the effect of alteration by the granite. Under the microscope these veins are found to consist chiefly of white mica and fluorite in minute particles. In some veins corundum, spinel, and blue tourmaline occur also; and it is significant that whereas the tourmaline in the Ulu Gopeng schists is brown, that in the clay is blue, and of a shade pale enough to be distinctly recognizable in a hand specimen. Only a few grains of brown tourmaline have been obtained by washing a quantity of clay. Moreover, the clay at the junction shows lamination with bright colours, described elsewhere in this Magazine, which has no counterpart in the Ulu Gopeng section. If therefore we assume the clay to be schists like those at Ulu Gopeng weathered so as to lose all trace of bedding we have to explain why alteration by the granite produced such different results on the same material. The granite

must have been intruded when the bedded rocks were fresh and unweathered deep below the surface, and the only solution seems to be that the clay now exposed on the surface never resembled the Ulu Gopeng schists.

In the earlier publication a section was described on the Kramat Pulai mine. This was one of those rare cases where I had another observer (Mr. W. R. Jones) to check the accuracy of my sketch before the section was destroyed. Reference to it will show that if the boulders are portions of a continuous hard bed broken up the kaolin vein must have been broken up too, which is not the case.[1]

"Laterite" was mentioned above. This has an interesting bearing on the question under discussion. When shales and schists are weathered at the surface, generally, but not always, these masses of ironstone are formed, and as the iron is gradually deposited along bedding-planes and joints the masses exposed at the surface frequently preserve the structure of the rock they replace and are themselves a guide to the nature of the country rock. In mining operations these ironstone growths often give much trouble, as for instance at Bruseh, and if the Kinta clays and boulder-clays were weathered shales or schists one might reasonably expect to see numbers of them in the soil or in mines where the soil has been worked away. But such masses do not occur, as far as I know. The clays are sometimes hardened by the deposition of iron, but there is no shaley or schistose structure preserved. On the other hand, where clearly bedded rocks occur, as at Redhills and near Batu Gajah, ironstone replacements do occur, and in ditches near the latter locality one can see how the ironstone is gradually deposited as the shale weathers away.

Another point to be considered is this. If we conclude that the clays are formed by shale, etc., sinking over limestone as it dissolves away, we should first be sure that there has been sufficient alteration in the level of the limestone to produce the result. It is impossible to obtain precise information, but although there are doubtless places where deep cavities have been hollowed out, there is some evidence pointing to the general lowering of the limestone surface having been slight.

Usually the limestone surface is a mass of pinnacles, but for some time there was exposed, in the bottom of a mine at Tekka, Sungei Raia, a large and almost flat platform of limestone that seemed to be the original surface. Where the platform ended there were pinnacles as in other localities. Again, at Gopeng, under the Gopeng Beds, which show stratification, there is a limestone floor. This shows as much irregularity as the limestone floor elsewhere, but the beds above have retained their stratification, except immediately above the soluble rock, where, however, a disorganized pebble-bed, if that

[1] Mr. Jones now seeks to explain this vein as an effect of different coloration in the clays, but if the Kramat Pulai vein can be thus explained the same holds good for all the kaolin veins. I am quoted as describing a case at Pusing Bahui which Mr. Jones says is similar, although he did not see it. It was, as a matter of fact, different from the Kramat Pulai vein in that it had no sharp boundaries and did not consist of kaolin.

be the correct interpretation of its peculiarities, can be traced into clearly marked strata. If these deposits at Gopeng retain their bedding, why do not the others do so also if they are only weathered shale and schist?

Some mines have afforded exceptional facilities for studying deep tin-bearing deposits, namely the Tronoh and Tambun mines. The Tronoh mines contain shales and rich tin-bearing clay, and the question is whether the latter are the shales weathered and broken up over dissolving limestone or a distinct formation. It might be argued with reason that taking this mine alone the former is the better explanation and that the tin-ore was introduced by granitic intrusions along the fault. I find it hard, however, to adopt this view in its entirety. On the west are good sections of bedded shale and quartzite, and I am informed that they carry only a little tin, although granitic intrusions occur and also quartz veins, in one of which wolfram has been found. Going eastward one comes suddenly on clays without bedding, but with pebbles in some quantity and very rich tin-contents. If the pebbles are derived from the harder bedded rocks on the west and the quartz veins one would expect them to be of greater size and more angular; and, moreover, seeing that granitic intrusions occur in the bedded rocks it is difficult to explain the comparatively large amount of tin-ore in the clay if it all comes from granitic intrusions also. It might, however, be suggested that the rich ore is derived from a long lode in shales, now broken down to clay. I once saw a section in a small mine to the south of the Tronoh Ltd. mine that might have been thus interpreted, but nothing could be proved, and at the present time there is nothing visible supporting the view. Nevertheless it may be that some such interpretation as this is the correct one, and weak points in the theory that the clay is a distinct formation overlying the limestone are that nothing is known of it to the east underneath the sand and masses of vegetation where the limestone rises nearer the surface, nor has anything been proved concerning the presence of tin-bearing clay under the bedded rocks on the west.

In Towkay Chung Thye Phin's mine the distribution of the ore is suggestive of a lode. On one side is the crystalline limestone, coming near the surface of the ground. On the other side is a steep bank cut in the shale and quartzite showing innumerable little stringers of kaolin and veins with tourmalinized shale on either side. The ore-bearing clay occurs along the junction of the limestone and shale and quartzite. In the portion of the mine nearer the Tronoh Ltd. mine it is a narrow band of a few feet in width only. In the gut in the centre of the photograph it is said to die out altogether. Beyond it opens out again.

In the Tronoh South mine again the run of the ore suggests a lode rather than a detrital deposit; but in all these Tronoh mines there are objections hard to dispose of if we are to regard the "Tronoh lead" as a weathered lode. In the first place, on the west wall of the mines the effect of emanations from the granite is seen in the tourmalinization of the shales bordering the small veins. The shale is hardened and charged with minute crystals and grains

of brown tourmaline. I have not seen anything like it in the rich tin-bearing ground.

Again, in the Pusing neighbourhood veins have been found and worked in clay just as soft as the Tronoh pay-dirt. They were probably connected with the granite by fissures through the limestone. In one case the vein was at a contact of granitic rock and clay. But these veins preserved their identity as veins. There was no mistaking them for anything else. At Tronoh, on the other hand, the tin-bearing ground strongly resembles, if it is not, a detrital deposit. If it were a broken-down lode we would expect to find at least some trace of an "iron-hat" containing tin-ore, lumps of hardened shale, with tourmaline, and large masses of tin-ore. I have already mentioned the only section that I can remember as even suggesting a lode. A hard mass with quartz seen lately in the Tronoh Ltd. main lumbong also looked as though it might be evidence of a lode, but the tin-ore was stated to be all to the east of it, and it was only a weathered quartz-vein at the edge of the shales.

At the North Tambun mine one could see, early in 1916, soft shales showing distinct bedding lying on the limestone and unbedded clay rich in tin-ore hard by.

In Towkay Leong Fee's mine at Tambun highly inclined bedded rocks lie side by side with clay very rich in tin-ore. The latter sometimes shows a trace of lamination, but I have not seen any section where bedded can be traced into unbedded rocks. They appear to be distinct, but one of the Perak mining community who has had a long experience of the mine holds the view that the clays are the bedded rocks very much weathered, and tells me that in the latter good tin-values have been found. In the North Tambun mines the shales retain their bedding immediately above the limestone, and it is difficult to understand why in this and in Towkay Leong Fee's mine the bedded rocks have retained their bedding if the others have lost it, seeing that both are equally soft and the position of the limestone is such that one cannot help expecting it to extend under the bedded rocks.

At New Tambun also the bedded rocks occurred in juxtaposition to the clays. The former were traversed by numerous small kaolin veins. They yielded a little tin-ore throughout, whereas the clay was comparatively rich. No limestone was met with below the bedded rocks.

In the Tronoh and Tambun mines, and also elsewhere, it might be argued that in addition to the disturbing effect of the limestone surface being lowered, the bedding of shales and schists has been destroyed by the media that brought the tin-ore; in fact, this view was put forward during a discussion on a paper read in Ipoh some years ago. This would account for the greater quantity of tin-ore in the clays, but it is difficult to reconcile the theory with observations elsewhere.

In Intan, in Upper Perak; at the Ulu Gopeng mine; at Bruseh, in Batang Padang; at Jeher, and near Tanjong Malim; and at Pantai, near Kuala Lumpur, bedded shale and quartzite have been invaded by tin-bearing media on a large scale, but I do not remember

anything that supports the explanation put forward above. In every case the bedding is clearly preserved, although the rocks are soft.

Another possibility might be put forward. When some limestone dissolves away a residual mass of insoluble impurities is left behind. Are the clays and boulder-clays simply the residue left behind as the limestone surface was lowered by solution? If the Kinta limestone were impure this would account for much, but it would not account for the beds with boulders of granite at Gopeng, and I think that a fatal objection to it is that analysis shows the limestone to be an exceptionally pure carbonate rock. Analyses by Mr. C. Salter of two typical specimens of limestone from near Menglembu gave the following results:—

	No. 1. per cent	No. 2. per cent
SiO_2	·27	·26
Al_2O_3	·26	·26
Fe_2O_3	·13	·09
MgO	1·30	3·75
CaO	54·50	51·80
CO_2	44·25	44·82
	100·71	100·98

At the Tekka granite-junction the veins containing fluorite and the blue tourmaline veins suggest association with limestone; the fluorite because it is calcium fluoride, the tourmaline because similar tourmaline has been found in limestone on the Tekka Ltd. mine and at Siputeh. But I do not think that anyone who has examined the crystalline limestone and the clay at Tekka could conclude that the latter is the residual impurity of the former. If it were, and if the veins were originally encased in limestone, the latter could not possibly retain their course as veins now, because the diminution of bulk of the containing rock would be enormous.

Finally, it may be said in favour of the clays and boulder-clays having been deposited as clays and boulder-clays that in Sarawak there have been exposed, in the gold-mines of Bau and Bidi, many sections of shale over limestone, and generally, as far as I can recollect, the bedding in the latter was distinctly preserved, although the limestone had been attacked by water and carved into irregular pinnacles just as much as in Kinta.

If the clays and boulder-clays were laid down as such the only explanation of their peculiarities that can be adduced is that they are of glacial origin. The evidence against this and against the deposits being in their original condition must now be given.

The first objection to the glacial theory is that on the west side of the valley boulders of different rocks are not mixed up as they usually are in boulder-clay. The tourmaline-corundum rocks are not mixed with boulders of granitic rocks. On the Siputeh Ltd. property I have not seen any tourmaline-corundum rocks, although in the Pusing Bharu mine they were very abundant, and have also been seen at Siak. On the other hand, in the Siputeh mine are abundant boulders of tourmalinized quartzite with tin-ore and

boulders of quartz. Some years ago one or two granitic boulders were found in this mine, but the great majority are those just described, and in 1914 a section was laid bare in the tributor's mine that affords the strongest evidence against a glacial origin that has been found. The section is in a big open-cast mine. On the near side of the mine there is a high limestone wall and lignite. The limestone extends to the bottom of the mine, which is about 120 feet deep, and above it, on the far side, is a section showing boulder-clay on the left, and in the centre and on the right shale and quartzite very much disturbed. About the same time that this section was first seen a quartz-vein was exposed in the limestone at the bottom of the mine, and, as the boulders in the clay are all quartz or tourmalinized quartzite, the facts point to the boulder-clay being much disturbed quartzite and shale beds, together with a quartz-vein, completely disorganized in a deep cavity in the limestone.

This section is the only instance of a boulder-clay being exposed in close proximity to bedded rocks from which the boulders could be derived, but the same section showed a further point that is difficult to understand. On the left of the section and some yards away from the bedded rocks were two elongated patches of clay rich in tourmaline. These might possibly represent portions of the bedded rocks rich in tourmaline, but their form suggested that they were the result of the production of secondary tourmaline in the clay, in which case the formation of the boulder-clay must have been pre-granitic. This, however, is by no means certain, and the patches cannot be taken as an objection to the clay and boulders having been derived from the shale, quartzite, and quartz-vein at some time. In this mine one must conclude that the boulders are not of glacial origin, but are the remains of a tin-lode in shale and quartzite overlying limestone.

Another piece of evidence obtained since the earlier edition was published concerns the huge boulders of quartz in the Kinta Association mine at Tanjong Rambutan. I have been informed that at one period during the work a section of a big quartz-vein was exposed from which the boulders could have been derived. I did not see this section myself.

On the Tekka Ltd. mine, and in the sections to the south, where the clay is in contact with the granite, there is another point that must be mentioned. There are no boulders of any size to be seen near the granite. For conclusive evidence of the clays being glacial one requires boulders at the junction with the granite. They were found in the Kramat Puali section, however.

The doubt concerning the origin of the tin-bearing clay at Tronoh and Tambun can be cited against the glacial theory.

The absence of striæ on boulders is also against this explanation, but with rocks so weathered as these are, striæ cannot be expected, if they ever existed, except in the case of boulders of corundum or tourmaline-corundum rocks. Nothing has been found that I can regard unreservedly as glacial striæ. A glaciated pavement of limestone would be destroyed by solution.

Lastly, a powerful argument against the glacial theory is that with

the exception of one section at Kacha mentioned earlier in this chapter, but which cannot be seen now, the clays and boulder-clays have only been seen resting on limestone. An exposure of them above argillaceous or arenaceous rocks, or above any rock not soluble to the extent that limestone is soluble, would remove all doubt of their having been deposited as clays and boulder-clays, but no such section can be pointed to.

The deposits that were described first as the "Gopeng Beds" differ from the foregoing in being in part stratified. Sections in the deep excavations now being worked and other sections show that this stratification is more distinct than was formerly thought to be the case, but there are associated clayey beds with isolated boulders such as those figured in the earlier edition (pl. v, fig. 3; pl. vii, fig. 3; pl. xvi, fig. 1), and when that edition was prepared a glacial origin for them was the only satisfactory explanation. Nothing further has been learned about the first two cases illustrated by the figures, but other sections have been seen where the boulder-beds are immediately above limestone and could be interpreted as stratified beds disorganized by sinking over limestone. This includes deposits invaded by kaolin-veins. I am still uncertain that this view of pebble-beds being broken up and mingled with clay to simulate boulder-beds is the best. It is insufficient to explain the section in which the big boulder figured in pl. v, fig. 3, of the earlier edition occurred; and the boulder figured in pl. xvi, fig. 1, and other isolated boulders occurred on some of the highest land.

It is difficult to believe that the corundum boulders found at Pulai and on the Tekka Ltd. mine were deposited in their present position by water-action. An alternative view to their being dropped from ice into fine silt is suggested, however, by an exposure on Tekka which has only recently been laid bare. In stiff clay overlying the limestone corundum boulders were found in great numbers, many being over 100 lb. in weight. When the limestone floor was exposed, it seemed possible from the distribution of the boulders and the position of some of them that they had formed a vein in the limestone. No corundum could be found embedded in the limestone, but that, of course, is not a fatal objection to there having been a vein, the walls of which were dissolved away. Some of the corundum boulders are angular, some well rounded. Like other specimens found at Pulai and Tekka, the surface of the boulders is often pitted as though some mineral intergrown with it had been dissolved away. I have not obtained any evidence that it was calcite from the form of the cavities, but that is possible.

In Selangor evidence has been found by Mr. Jones of faulting in recent alluvium. Figures in the older edition show complicated faulting in the deposits under discussion, and we have to consider the possibility of the latter being recent alluvium faulted and in part disorganized owing to the solution of the underlying limestone. It is, I suppose, possible that faulting such as this could be produced by such a cause, but it is unlikely; and the evidence of the kaolin-veins is directly opposed to the beds being recent. Accumulated observations of the form of the kaolin-veins and their junction with the clay

and pebble-beds point to their being intrusive The first vein I saw was on Kinta Tin Mines Ltd. In 1908 the top of this vein was visible and was sketched. In section it could be seen terminating in a thin stringer of kaolin in the red clay. Later on the top was cut away by a monitor and the vein exposed near the limestone. The junction with the clay is shown in plate x of the old edition, as also another junction between a kaolin-vein and the clay. In vol. lxviii, 1912, of the Quarterly Journal of the Geological Society, p. 149, fig. 4, a figure is given of a kaolin-vein and a tourmaline-vein on Tekka Ltd.

The evidence of the form of the veins is strengthened by a case where a kaolin-vein was found to be bordered at its junction with the clay by a mica-tourmaline rock resembling a rock found at the junction of granite and clay on Tekka Ltd. This rock is markedly different from the body of the vein itself and can only be interpreted as the result of metamorphism of the clay. The tourmaline is blue, as on Tekka Ltd.

Sections of kaolin-veins have been exposed in beds high above the limestone and also in excavations where they can be seen close to limestone. In the latter one may see what I believe to be the effect of the settling-down of the clay, pebble-beds, and kaolin-veins, as the limestone dissolves. It shows itself sometimes as a brecciation at the junction, an excellent example of which was photographed some years ago. In other cases the junction of kaolin-vein and clay is very confused, and pieces of the kaolin are separated from the parent vein.

Against the evidence of the kaolin-veins must be set the buried trees that are occasionally found. I have explained these as being trees that have fallen into old and forgotten excavations. The sandy casing found round some of them supports this view (*vide* Q.J.G.S., lxviii, pp. 150–1, fig. 5, 1912), but a section has lately been photographed, unfortunately too late for illustration; that is a puzzle I am unable to solve. It occurs on the Gopeng Consolidated property. On the right is a very clearly-marked fault with grey pebble-beds and clay on the right of the fault, and the same beds, stained red and disturbed, on the left. To the left of the fault is part of a big kaolin-vein. It looks as though it had been slightly bent by movement of the clay, but can only be regarded as intrusive, since it is the same vein as that mentioned above as being bordered by mica-tourmaline rock. There are masses of kaolin, isolated in section, which may be joined to the parent vein further in, or may be portions sheared off by settling over the limestone. The fault does not touch the main mass of kaolin. Only six feet, or thereabouts, above the kaolin is a mass of wood around which I could find no casing when I saw it some days after it was first uncovered. Here, then, we have a kaolin-vein that has effected alteration of the rock it is intruded into, well-preserved wood 6 feet from it in the same clay, and a fault that does not help matters one way or the other.

In an earlier chapter the possibility was touched on of there being in the Kinta Valley detrital deposits belonging to the era when the Peninsula was united to the Archipelago or to that when the former was a group of islands. This must be considered briefly in connection with the Gopeng deposits.

One reason against regarding these bedded deposits as recent alluvium is their position. They form part of a watershed. They rise to a considerable height above sea-level; they are as high as much of the land formed of shale and quartzite in the centre of the Kinta Valley; and they differ from the recent alluvium in containing much less vegetable matter, the few buried trees being the only material of this nature. Their position, however, does not preclude their being the remnant of deep alluvial deposits that filled a valley when the Peninsula and the Archipelago were united, but the difficulty is to reconcile with this possibility the evidence of the kaolin-veins, which must in that case have been intruded into surface deposits.

The same objection applies to their being formed in the sea when the Peninsula was a group of islands, and there is the further objection that the deposits at Gopeng do not resemble the familiar coast deposits of to-day. If they are considered to be of marine origin we have to face the absence of marine organization and mangrove mud.

Both in the case of unbedded and bedded deposits there is still the question of the origin of the tin-ore to be noticed. Its most striking feature is its angularity, which was shown in plate iv of the earlier edition. On the west of the Kinta River there is no doubt that some of the ore was brought by media that came through the limestone from the granite of the Kledang Range or direct from granitic intrusions such as that at Pusing Lama. But this is not sufficient to account for all the ore, and I think the only satisfactory solution is that detrital ore derived from an older granite was added to by a younger granite. It must be remembered that large areas of limestone bedrock have been exposed showing no veins by which tin might have come to the rocks above.

At Tekka and Gopeng the angularity of the detrital ore is against its being alluvial, and on the Kinta Tin Mines Ltd. property and elsewhere evidence has been found of enrichment from the kaolin-veins and the granite of the Main Range. The detrital ore must be older than the kaolin-veins, and therefore, we must conclude, older than the granite of the Main Range, and it should be kept in mind that the granite fragments in the altered volcanic ash of Pulau Nanas, near Singapore, show that a granite mass older than the granite of the Main Range once existed (Q.J.G.S., lxvi, p. 428, 1910).

On pp. 39 and 40 of the 1913 publication I gave some objections to these Kinta tin-deposits being held to be of glacial origin. The Siputeh section is certainly a further objection, but, seeing that extensive glaciation is known to have existed on Gondwanaland about the time when these beds were laid down, a glacial origin appears to meet more of the facts than any other explanation.

III.—Some Pelecypod Shell-fragments described as Cirripedes.

By Thomas H. Withers, F.G.S.

Among a number of Cirripede plates from the Chalk Marl and Cambridge Greensand of Cambridge submitted to me some time ago, were certain fossils which at first puzzled me considerably.

Although there were more than twenty examples, all came apparently from the same side of the animal, that is, they were not left and right, and this led me to suspect that they were not Cirripede valves, and to examine them more closely. One edge close to the narrow end of the shell was then seen to be broken quite clean and straight, and on comparing these fossils with some Pelecypod shells from the same horizon it was quite clear that they were the anterior ears of right valves of *Aucellina gryphæoides* (Sow.) (Text-fig. 7, p. 170), a shell belonging to the family Pteriidæ (see H. Woods, Pal. Soc. Monogr. Cretaceous Mollusca, 1905, vol. ii, p. 72, pl. x, figs. 6–13). Other specimens submitted at various times from Jurassic and Cretaceous rocks, turned out on examination to be the anterior ears of the right valves of Pelecypod shells like *Pecten*, and a number of such specimens were included among some Cirripede plates from the Chalk of Rügen obtained for the British Museum by Frau Agnes Laur.

Since the superficial resemblance to Cirripedes of the anterior ears of the right valves of *Pecten*-like shells and other shell-fragments, has resulted in their mistaken identification by collectors, even those of experience, it is not surprising that some authors should have described and figured such fossils as species of Cirripedia.

Thus, Darwin has figured as a carinal-latus of the Cirripede *Scalpellum solidulum*, the anterior ear of a *Pecten* from the Cretaceous, and a recent examination of the holotype of the supposed Liassic Cirripede *Pollicipes alatus*, shows that this is another case of the anterior ear of a Pelecypod being mistaken for a Cirripede valve. One or two other instances have been noticed while going through the Cirripede literature, and it was thought advisable to include them in the present note, for this will serve not only to call attention to these remains, but will be a further step towards ridding the Cirripedia of all such non-Cirripede material.

ZOOCAPSA DOLICHORHAMPHIA H. G. Seeley. (Text-fig. 1, p. 170.)

1870. *Zoocapsa dolichorhamphia*, H. G. Seeley, Ann. Mag. Nat. Hist., ser. IV, vol. v, p. 283.
1877. ,, ,, ,, (=*Avicula* or *Pecten*): H. Woodward, Brit. Mus. Cat. Brit. Foss. Crustacea, p. 146.
1891. ,, ,, ,, (=*Avicula* or *Pecten*): H. Woods, Cat. Type Foss. Woodwardian Mus. Cambridge, p. 132.

Since this fossil from the Lias of Lyme Regis was described as a sessile Cirripede by Professor Seeley, an examination of the type was made by Dr. H. Woodward, who stated in his Catalogue (1877, p. 146), "I am inclined to consider the 'tergum' to be the wing of an *Avicula* or *Pecten*, and the underlying 'scutum' to be another portion of the same shell." H. Woods (1891, p. 132) subsequently recorded the fossil as "*Avicula* or *Pecten*".

No figure has yet been given of this fossil, and only a very inadequate idea of it can be deduced from the description. The specimen really consists of seven or eight fragments of Pelecypod

shell embedded closely together, and only one fragment shows the outer surface. From their colour and appearance they evidently belong to more than one form of shell, but it is impossible to discover much from the inner surface of mere shell-fragments.

The most conspicuous fragment is the irregularly triangular shell-fragment marked II in Fig. 1, and this was Seeley's "tergum". It is really the anterior ear of a right valve of a *Pecten* with a part of the remaining shell, and shows the inner surface. The sub-cylindrical shell-fragment regarded by Seeley as continuous with it and as the "beak" of the "tergum", does not appear to me to belong to it. Above the "tergum" is a four-sided shell-fragment (I) called by Seeley the "scutum", but this is an indeterminable shell-fragment quite unlike the inner surface of the scutum of a Cirripede.

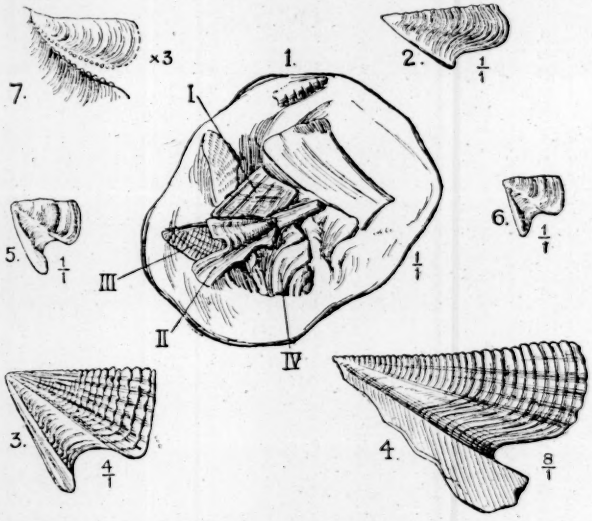


FIG. 1. *Zoocapsa dolichorhamphia* Seeley.
,, 2. *Pollicipes alatus* Tate. (After Tate.)
,, 3. *Scalpellum solidulum* Steenstrup sp. (After Darwin.)
,, 4. ,, ,, ,, (After Marsson.)
,, 5, 6. ,, ,, ,, (After Karakasch.)
,, 7. *Aucellina gryphæoides* Sowerby sp. (After Woods.)
(Figures drawn by Miss G. M. Woodward.)

Projecting from under the "tergum" is another fragment (III) with slightly elevated wavy ribs, crossed at right angles by growth-lines. This is the only fragment showing the outer surface, and the ornament of it agrees very closely with that of the Pelecypod *Lima gigantea*, Sowerby. It represents Seeley's "upper latus". On the opposite side of the "tergum", is another fragment (IV) regarded by Seeley as one of the compartments, but though Molluscan it is impossible to say to what shell it belongs. Professor Seeley stated, "Altogether the plates preserved would incline one to suspect that there were no more." It is apparently to be understood from this

that he did not include as belonging to his supposed Cirripede, the three shell-fragments unnumbered in the figure.

Not only did Professor Seeley found a new genus for these shell-fragments, which obviously belong to different Pelecypods, but he regarded them as belonging to a Cirripede which was the type of a new family intermediate between the Balanidæ and Verrucidæ, with peculiar affinities towards the Lepadidæ. A Cirripede valve is a well-formed structure, and in no way resembles the fragmentary portions of shell in this fossil.

POLLICIPES ALATUS R. Tate. (Text-fig. 2, p. 170.)

1864. *Pollicipes liassicus*, R. Etheridge, Quart. Journ. Geol. Soc., vol. xx, p. 114 (nomen nudum).

1870. *P. alatus*, R. Tate, Appendix I to Ann. Rep. Belfast Nat. F. C., p. 23, pl. i, fig. 6.

This shell-fragment, which came from the Lower Lias "*A. angulatus*" zone of Island Magee, Antrim, was originally noticed by R. Etheridge as a scutum of *Pollicipes*, and although he gave neither description nor figure, he proposed for it the name *Pollicipes liassicus*.

R. Tate subsequently described and figured it as a scutum of *Pollicipes* under the new name *P. alatus*. He remarked—"The single scutal plate here figured is the one to which Mr. Etheridge applied the MS. name of *P. liassicus*; but, as another species was described by Dunker with a similar denomination, *P. liasinus*,[1] it appears to be advisable not to adopt Mr. Etheridge's provisional name. I, therefore, have selected that of *P. alatus*."

The holotype of *P. alatus* is now in the Geological Survey Museum, Jermyn Street, registered 28849. Examination has shown that it is not a Cirripede valve, but merely the anterior ear of a right valve of a *Pecten*. Dr. F. L. Kitchin, who kindly examined the specimen to see if the species could be determined, made the following confirmatory report: "The type of Tate's *Pollicipes alatus* is undoubtedly the anterior ear of a right valve of a *Pecten*. I can only say that it belongs to one of the smooth Pectens that have been commonly ascribed to *P. calvus*, Goldfuss. Goldfuss only figured left valves, and I am not absolutely sure that any of the specimens in this museum ascribed to his species are truly identical with it. But Tate and others have referred certain smooth forms from the *angulatus* and overlying zones to this species, and in the absence of an exhaustive enquiry based on much material it is usual to adopt this provisional naming. It is not unlikely that more than one species has been thus determined among our British material, but it is to one of these that the supposed *Pollicipes* belongs. The specimen is such a fragment that a precise determination of species is scarcely to be hoped for."

In a paper "On a New Species of *Pollicipes* from the Inferior Oolite of the Cotteswold Hills", GEOL. MAG., 1908, p. 351,

[1] The name *Pollicipes liasinus* was given by Dunker (1848, *Palæontographica*, Bd. i, p. 180, pl. xxv, fig. 14) to a supposed tergum from the Lias of Halberstadt, and although the figure is not at all like that of a tergum of a Cirripede, an examination of the specimen would be necessary before one could give an opinion as to its nature.

Mr. Linsdall Richardson states, "I have found several examples of plates belonging to a species inseparable from this one [*P. alatus*, Tate] in the Lias of oxynoti-armati hemeræ that was exposed when excavations were being made for a new gas-holder at the Gloucester Gas Works." Mr. Richardson most kindly sent me examples of the supposed Cirripede plates from that locality, and these confirm the conclusion already arrived at that they, like *P. alatus*, merely represent the right anterior ears of some form of Pecten-like shell.

Scalpellum solidulum Steenstrup sp. (Text-figs. 3–6, p. 170.)

Steenstrup (1839, Krøyer's Naturhist. Tidsskrift, Bd. ii, p. 412, pl. v, figs. 14, 14*) founded this species on an undoubted carina of a Cirripede from the Chalk of Scania. Darwin, however, when redescribing the species in his monograph (Pal. Soc. Monogr. Foss. Lepadidæ, 1851, p. 42, pl. i, figs. 8*a–f*), included with a carina and tergum, a Pelecypod fragment (figs. 8*e–f*) from Köpinge, Scania, but this in no way affects the nomenclature of *Scalpellum solidulum*. This shell-fragment (Text-fig. 3), which was considered by Darwin to be a carinal-latus[1] of *S. solidulum*, really represents the anterior ear of a right valve of a species of *Pecten*.

A shell-fragment (Text-fig. 4) of the same nature from the Chalk of Rügen, was figured by Marsson (1880, Mitth. naturw. Vereine Neu-Vorpommern und Rügen, Jahrg. xii, p. 15, pl. i, fig. 15), and the figure given of that fossil is so good, and shows its fractured inner edge so well, that one can only wonder that it should have been described as a Cirripede valve.

Subsequently, N. I. Karakasch ("Les Cirrhipèdes du terrain crétacé de la Crimée," Trud. St. Petersb. Obsch. Estest., vol. xxxi, livr. 5, p. 14, pl. i, figs. 17, 18), no doubt following Darwin and Marsson, figured two similar shell-fragments (Text-figs. 5, 6) from the Chalk (Upper Senonian) of Bakla, Crimea, as carinal lateral valves of *Scalpellum solidulum*. These may not, however, belong to the same species of *Pecten* to which the shell-fragments figured by Darwin and Marsson belong.

Similar shell-fragments, which are undoubtedly the anterior ears of right valves of Pectens, were included with a large number of Cirripede valves in a collection of fossils sent to the Geological Department of the British Museum from the Chalk of Rügen, but, as in the case of those figured by Darwin, Marsson, and Karakasch, it would be a very difficult and unprofitable task to attempt to determine the species.

Conclusion.

While the present communication may be taken as showing that certain so-called Cirripedes from the Jurassic and Cretaceous Rocks are really the remains of Pelecypod shells, it must not be regarded as exhaustive. It deals only with those of which the originals can be examined, or as to the nature of which no doubt is possible. Some

[1] In his other memoir (1851, Ray Soc. Monogr. Lepadidæ, p. 245) Darwin thought that he was wrong in considering this to be a carinal-latus, and that it was probably an upper latus.

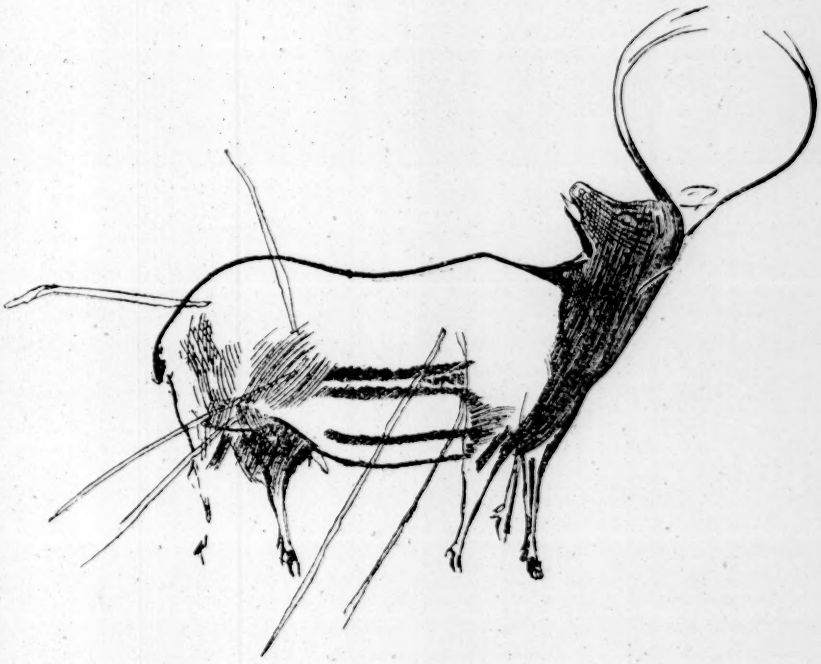
other Jurassic fossils figured as Cirripedes are very doubtful, and an examination of the originals will probably show that they do not belong to the Cirripedia, but from the descriptions and figures it is impossible to say what they really are.

NOTICES OF MEMOIRS.

Drawings in Spanish Caves.

Los Grabados de la Cueva de Penches. By Eduardo Hernández-Pacheco. Comisión de Investigaciones Paleontológicas y Prehistóricas, Mem. No. 17, Madrid, 1917.

THE Spanish Government is to be congratulated on the valuable memoirs on Geology, Prehistoric Archæology, Zoology, and Botany which are being issued in rapid succession from the National



Drawing of a hunted deer, pierced with arrows, on the wall of the cavern of La Peña, San Román de Candamo, Asturias, Spain. Original about 4 feet in depth.

Museum of Natural Sciences in Madrid. They are making known the scientific treasures of Spain in a manner which has not hitherto been possible; while their attractive style and their profusion of admirable illustrations render them all the more welcome. The memoirs on the prehistoric drawings in the Spanish caves are especially interesting, and the latest, by Dr. Hernández-Pacheco, maintains the standard we have now been led to expect.

The new memoir deals with incised drawings, chiefly of deer, in a remote cave in the province of Burgos. Like many of the other caves ornamented by Magdalenian man, it consists of little more than irregular crevices in the Cretaceous limestone and could scarcely have been used as a habitation. Dr. Pacheco thinks that the drawings were made there by the hunters merely under the impression that they would have some mystic influence on their success in the chase. Some of the deer seem to be represented as pierced by arrows, and Dr. Pacheco publishes for comparison with them a most remarkable incised drawing of a hunted deer lately found in the cave of La Peña, in San Román de Candamo, in Asturias. This drawing is so extraordinary that we venture to reproduce it here. It shows the deer pierced by several arrows, standing at bay, in evident distress, with protruded tongue. Of all the drawings of game hitherto found in the Spanish and French caves this is probably the most animated. The effect is even enhanced by the skilful use of lines of shading, and we cannot but admire the artistic powers of the old hunters who were able to produce such work on irregular surfaces in dark recesses underground.

A. S. W.

REVIEWS.

Memoirs of the Geological Survey.

I.—The Geology of the South Wales Coalfield. Part IV: The Country around Pontypridd and Maestêg. By A. Strahan, F.R.S., R. H. Tiddeman, and W. Gibson. Second edition, revised by W. Gibson and T. G. Cantrill. Memoirs of the Geological Survey, 1917. pp. ix + 160. Price 3*s.* 6*d.*

THIS memoir deals chiefly with the occurrence of the coal-seams in this area and their correlation, both at their outcrops and in the shafts of the mines, the character of the coals being described in a separate memoir dealing with the whole of the coalfield. The coal occurs mainly in the Lower Coal Series, but also to some extent in the Pennant Series; the Upper Coal Series is only present in one or two places in the area. The higher coals are more bituminous than the lower, and all the coals lose bituminous matter in a westerly and north-westerly direction, as is common in South Wales. Since the issue of the first edition numerous changes in the mines and mining have taken place; for example, steam coals are now no longer worked west of the Ogwr, while these coals are now being won from deep shafts sunk through the Pennant Series north and north-west of Llantrisant. Also the mining in the Ogwr and Avan valleys has been considerably developed as a consequence of the building of docks at Port Talbot, while the mining conditions of the Rhondda valleys have altered but little. The memoir contains chapters on the geological structure, the Mesozoic rocks, and the glacial deposits. It is illustrated by figures and vertical sections showing the correlation of the coal-seams, and is accompanied by a colour-printed map (Sheet 248) on the scale of one mile to the inch, which is a very good example of colour-printing.

W. H. W.

Indian Geology.

II.—The Geology of North-Eastern Rajputana and Adjacent Districts. By A. M. Heron, B.Sc., F.G.S., Assoc. Inst. C.E., Assistant Superintendent, Geological Survey of India. Memoirs of the Geological Survey of India, vol. xlv, pt. i. Calcutta, 1917. Price 4*s*.

THIS memoir deals with the re-survey of the above district, which is roughly contained in a triangle, with the cities of Agra, Jaipur, and Delhi at its apices; the original survey was carried out by C. T. Hackett in 1881 and is now out of date. The region is one of old folded rocks; these had been denuded to a peneplain, uplifted a second time, and now are in an advanced stage of the second cycle of denudation. The greater part of the district is covered with alluvium, but in the south-west part the old rocks come to the surface over a considerable area; the dips here are always high, and the hard bands stand up as ridges with broad valleys between: this close connexion between geological structure and topography is not common in this part of India.

Two distinct geological systems can be separated—an older, the Aravalli system of Archæan age, which may be correlated with the Dharwar system of Cental and Southern India, and a newer, the Delhi system, which is placed among the Lower Purana rocks. The interval separating the two systems corresponds to the Ep-archæan interval of North America.

The Aravalli rocks are exposed along the anticlines of the post-Delhi folding and consist of highly metamorphosed sediments with some intrusive granites, amphibolites, and quartz veins. The Delhi system begins with an inconstant quartzite which is overlain by the Rialo limestone. This limestone is a pure dolomite and usually forms low-lying country, with the exception of a few residual knolls of ironstone formed by metasomatic alteration. The succeeding Alwar series consists of quartzites, grits, and associated volcanic rocks, invaded by granites, pegmatites, and basic sills, now altered to amphibolites. These rocks are succeeded by a banded siliceous limestone, the Kushalgarh limestone, with which is associated a peculiar rock known as the "hornstone breccia". Finally, the Delhi system is completed by the Ajabgarh series, which is composed chiefly of clays with impure quartzites and limestones, and shows deeper-water conditions than the Alwar series.

The hornstone breccia which is found sometimes below and sometimes above the Kushalgarh limestone is a very remarkable rock. It consists of angular fragments of quartzites, identical with the Alwar and Ajabgarh quartzites, some pieces of slate similar to the Ajabgarh slates, and brecciated white vein quartz in a very finely granular matrix, the grains of which are coated with limonite, and which is occasionally sufficiently ferruginous to be used as an iron ore. It is suggested that the rock was formed by the crumpling of alternating beds of quartzite and slate under the stress of the post-Delhi folding; the quartzites, being brittle, would break and be pushed into the more yielding slates. Into this shattered rock,

veins of quartz were intruded, and some iron and copper were introduced into the matrix. Finally the whole mass was again brecciated by further folding.

The post-Tertiary formations which cover the old rocks over a great part of the area are partly the old alluvium of the Ganges and partly blown sand; a considerable amount of Kankar is found near the outcrop of lime-bearing rocks.

The district contains a fair number of minerals of economic importance, but unfortunately only in small quantity.

The irregular patches of Rialo limestone altered to hæmatite, which contain seams up to 7 feet in thickness, appear to be a workable proposition. A fairly large amount of iron has been smelted in this region in past times, but all the mines are now closed. Copper was mined on a considerable scale in ancient times, but none is now extracted.

The ore was chalcopyrite with pyrrhotite occurring along the junction between quartzite and slate at a horizon low down in the Alwars. Some kaolin is dug from the pegmatites, and steatite and a variety of building stones and marbles are also quarried in the district.

The memoir is illustrated by many excellent drawings and photographs of the scenery and structures in the field, photographs of specimens, and photo-micrographs of thin sections, and also by a geological map and a number of horizontal sections.

W. H. W.

Canadian Iron-ore.

III.—Iron-ore Occurrences in Canada. Vol. I. By E. Lindeman and L. L. Bolton. Department of Mines, Canada. pp. 71, with 23 plates and 1 map. Ottawa, 1917.

THE literature of the Canadian iron-ore deposits has till now been very scattered and difficult of access, and the Department of Mines has rendered a useful service by collecting all the available data in this convenient form. Iron-mining was not seriously developed in Canada till 1896, but since that date it has made rapid progress. Nevertheless, even now the proportion of ore mined in the Dominion is only about 15 per cent of that smelted in Canadian furnaces. The greater part comes from Newfoundland and the United States. Among the provinces Ontario is the largest producer: the most important source is the Helen Mine in the Michipicoten district. The ore is hæmatite, probably derived from siderite and pyrite by oxidation. Prospecting of large areas of banded jaspers and magnetite schists correlated with those of the Vermilion and Mesabi ranges in Minnesota has led only to disappointing results. The only promising occurrence of this kind is the Akitokan iron-range in Western Ontario, a magnetite ore with rather high sulphur content. In British Columbia there are some promising contact-deposits of magnetite which lie near coal and limestone, suitable for use as fuel and flux. The great furnaces of Nova Scotia chiefly use Newfoundland ore, but they were once supplied by local deposits of hæmatite, limonite, and ankerite in strata of Devonian age. These

seem to be contact-deposits, and they are rather rich in sulphur and phosphorus.

This report contains detailed descriptions of a great number of small occurrences of iron ores of almost every possible kind in all parts of the Dominion, but most of these do not seem likely to be of much importance, at any rate in the immediate future.

An interesting and useful appendix contains a detailed description of the Wabana mine in Newfoundland, now one of the largest iron-mines in the world, which supplies much of the ore for the Canadian furnaces. There are five beds of ironstone, from 5 to 30 feet thick, intercalated in Ordovician sandstones and shales. The ore is chiefly hæmatite, with some siderite and chamosite. The iron content is on the average 53 per cent, with silica up to 10 per cent and about 0·85 per cent of phosphorus. The ore-reserves are very large; a conservative estimate is 2,000,000,000 tons, and this figure may eventually be much exceeded. The mines are very conveniently situated for shipment of the ore, being close to the coast, where the water is sufficiently deep for large ships close in shore. The loading facilities are so extensive as to permit the loading of 5,000 tons of ore per hour. Part of the workings extend under the sea.

It is interesting to note that a large use has been made of magnetic surveys in investigating the iron-ore deposits of Canada, as this method was found to give useful results in Sweden.

R. H. R.

Artesian Waters of Australia.

IV.—The Problem of the Great Australian Artesian Basin. By A. L. du Toit. Journ. Proc. Roy. Soc. N. S. Wales, vol. li, p. 135, 1917.

In the light of his extensive experience of South African geology Dr. du Toit has re-examined the whole problem of the origin of the great artesian basin of Australia. Professor Gregory concluded, in opposition to the views of many Australian authorities, that the water was partly of magmatic origin and partly water included in ancient sediments during their deposition, only a small part being of modern meteoric origin; Mr. Symmonds considered that most of the water was juvenile in the sense of Suess. Dr. du Toit's views agree in the main with those of Professor Gregory in that he regards the waters as originating from three sources: (1) residual (Mesozoic), (2) plutonic, (3) Tertiary. The bulk of the Mesozoic water is believed to have been replaced by alkaline water derived from igneous intrusions: these waters are rich in sodium carbonate. On the eastern side of the basin early Pleistocene surface water drove out much of the still earlier accumulation and carried salts downwards. However, Dr. du Toit believes that at the present time the meteoric source is of most importance in keeping up the supply, though much of the older water may still remain. The notable and alarming falling-off in the yield of the wells observed of late years suggests the urgent need for efficient Government control of borings in the artesian area.

R. H. R.

V.—A Review of Mining Operations in the State of South Australia during the half-year ended June 30, 1917. No. 26. Compiled by Lionel C. E. Gee, S.M. Adelaide, 1917.

IN addition to the mineral statistics for the half-year this review contains an account of the Government diamond drilling operations, with logs of the bores, an account of several districts where there are mineral deposits which seem worth further prospecting, and an account of several mines which are either closed down or doing little work, with suggestions for their improvement. Among the deposits not yet fully prospected are deposits of apatite and graphite and also a large pyritic quartz lode which is regarded as a possible source of sulphur.

The apatite deposit is situated at Boolcoomatta Spring and consists of pegmatites occurring in Pre-Cambrian gneisses and schists. The pegmatites are very coarse-grained, containing felspar crystals up to 6 inches in length and plates of muscovite up to 1 inch in width. There are considerable numbers of veins, of which a fair proportion contain apatite in amounts varying from 5 to 60 per cent. The graphite deposits are situated chiefly in the southern part of Eyre's peninsula and consist of graphite schists in a series of gneisses, schists, and quartzites of Pre-Cambrian age. The outcrops are much weathered and decomposed, so that a fair determination of the flake graphite present cannot be made, but it is suggested that the quality will improve in depth when the oxidized ferruginous zone is penetrated. This deposit is regarded as an important one owing to the present large demand for flake graphite for the manufacture of graphite crucibles. The review shows great enterprise on the part of the Government geologists in seeking out new deposits and in trying to revive those mines which for various reasons have ceased work or are likely to be closed. W. H. W.

VI.—A New Test of the Subsidence Theory of Coral Reefs. By R. A. Daly. Proceedings of the National Academy of Sciences, vol. ii, p. 664, 1916.

THE author points out that during the formation of atolls according to Darwin's theory a concavity or "moat" must have been formed between the up-growing reef and the subsiding island. The filling of this moat, which has never been properly discussed, affords another test of the applicability of the theory. The moats have always been completely obliterated and the lagoons are very shallow. The possible source and means of transport of the material required for this filling are discussed in detail by the author. The lagoon floor is generally sandy and not covered by growing coral and other organisms, while the transport of sand by waves and currents can only be small and local. The levelness of the floor is inconsistent with filling by this means. The general conclusion is drawn that the processes mentioned are not adequate to explain the facts; and that existing coral-reefs are new upgrowths from platforms formed previously to and independent of reef-growth. The final preparation of the platform is supposed to have taken place during the Glacial period. R. H. R.

VII.—New Fossil Corals from the Pacific Coast. By Jorgen O. Nomland. University of California publications in Geology, vol. x, No. 13, pp. 185–90, pl. v, 1917.

Five new Tertiary Corals are described and figured, namely, *Astrangia boreas*, n.sp., Pleistocene (?), Douglas I., South-Eastern Alaska; *A. grandis*, n.sp., Pliocene, Middle Fernando series, Guadalupe, Santa Barbara County, California; *Astreopora occidentalis*, n.sp., Tertiary (?), near Newport, Oregon; *Caryophyllia oregonensis*, n.sp., Oligocene, Astoria series, near Smith's Point, North-Western Oregon; *Dendrophyllia californiana*, n.sp., Oligocene, *Agasoma gravidum* beds, near Walnut Creek, Contra Costa County, California. An undetermined species of *Balanophyllia* also is recorded from the Pliocene, Middle Fernando series, Fugler Point, S.E. of Santa Maria, Santa Barbara County, California, which is of interest as the "genus has heretofore been unknown in the Tertiary deposits of the Pacific Coast later than the Oligocene".

Finally, an Oligocene Coral-fauna is mentioned, consisting of *Balanophyllia* sp., *Flabellum* sp., *Paracyathus* sp., *Pocillopora* (?) sp., *Sphenotrochus* (?) sp., and two species of *Trochocyathus* "associated with *Dendrophyllia hannibali*, Nomland, or in the same series of beds as that species", in the Astoria group of South-Western Washington.

W. D. L.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

1. Annual General Meeting.

February 15, 1918.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The Reports of the Council and the Library Committee were read. It was stated that there had been a total accession of 29 Fellows in the course of 1917. During the same period the losses by death and resignation amounted to 43. The total number of Fellows on December 31, 1917, was 1,220.

The Balance-sheet for that year showed receipts to the amount of £2,966 10*s.* 8*d.* (excluding the balance of £676 12*s.* 5*d.* brought forward from 1916) and an expenditure of £3,581 1*s.* 6*d.* (including the purchase for £475 of £500 5 per cent War Loan).

The Reports having been received, after a brief discussion, the President handed the Wollaston Medal, awarded to Dr. Charles Doolittle Walcott, F.M.G.S., to Mr. William H. Buckler, Attaché to the Embassy of the United States of America in London, for transmission to the recipient, addressing him as follows:—

Mr. Buckler,—The Wollaston Medal, the highest honour at the disposal of this Society, is conferred upon Dr. Charles Doolittle Walcott in recognition of his eminent services to Geology and Palæontology, more particularly among the older fossiliferous rocks of North America. While his administrative work, both on the United States Geological Survey and at the Smithsonian Institution, has done much for science in his own country, his personal researches have excited interest and admiration wherever Geology is cultivated.

He has made important contributions to the history of the Algonkian formations, and his discoveries lead us to hope that the less altered of those ancient sediments may ultimately yield more abundant and definite relics of pre-Cambrian life. His detection of fish-remains in the Ordovician rocks of Colorado, again, carried back by a stage the earliest appearance of vertebrates in the succession of life-forms. But it is in the Cambrian strata that Dr. Walcott has found chief scope for his labours, which, pursued principally upon the American continent, have often had a world-wide importance. Realizing the dual part which the exponent of Palæontology is called upon to sustain, he has illuminated that science alike in its geological and in its biological aspect. Under the former head should be mentioned the determination and collation of the stratigraphical sequence in numerous districts, and the light thrown thereby upon the problems of Palæophysiography. In particular, Dr. Walcott's study of the geographical distribution of the Cambrian faunas, establishing the existence of two distinct provinces, marked a signal advance in this field. On the biological side his work has been no less fruitful in results. It is sufficient to recall the series of memoirs dealing with the Trilobites, in which he greatly elucidated the organization of that important group, and again his two handsome volumes on the Cambrian Brachiopoda.

In recent years, with energy which a younger man might envy, he has pushed his researches into the Rocky Mountains of Canada, amidst scenery which his beautiful photographs have made known to many. There he has been rewarded by the bringing to light of two richly fossiliferous horizons in the Middle Cambrian succession, including in one an assemblage of fossils marvellous for the perfect preservation of their detailed structure. The preliminary account of the discovery has aroused keen interest, and palæontologists eagerly await the full description by a master hand of this unique collection.

If by his official status, joined with his personal record, Dr. Walcott is in some sense representative of American geology, with its large opportunities so ardently embraced, the occasion may remind us that community of scientific interests is perhaps not least among the links which unite your country to ours. I have much pleasure, Sir, in placing this Medal in your hands for transmission to its recipient, and trust that his future career may include achievements no less brilliant than those which we commemorate to-day.

Mr. Buckler replied in the following words:—

Mr. President,—Mr. Page greatly regrets that a long-standing engagement prevents him from receiving this Medal in person. He has asked me to convey to you Dr. Walcott's deep appreciation of the honour awarded by your Society and to assure you that this feeling is shared by our fellow-countrymen. Let me thank you, not only for this high distinction conferred upon American Geology in the person of one of its leading representatives, but also for the wishes which you have expressed, and in which all Americans will heartily join, for Dr. Walcott's future labours.

As a former President of the Baltimore Society of the Archæological Institute of America, I may mention that Dr. Walcott presides over the Washington Society of that Institute, a fact reminding us that his wide interests include Archæology, the younger sister of Palæontology.

In these times and on such an occasion one cannot but recall—as you, Sir, have said—the community in scientific, as in literary and political, activity which exists between the English-speaking peoples on both sides of the Atlantic. It is significant that of the two American Institutions in which Dr. Walcott has served as Secretary, the Smithsonian was founded by an Englishman, the Carnegie by a Scotsman. The partnership in arms, which now as never before unites our peoples, cannot fail in the coming years to strengthen and to extend that scientific comradeship of which your tribute to Dr. Walcott is a signal recognition.

In handing the Murchison Medal, awarded to Joseph B. Tyrrell, M.A., to the Hon. Sir George Halsey Perley, K.C.M.G., High Commissioner for the Dominion of Canada, for transmission to the recipient, the President addressed him as follows:—

Sir GEORGE PERLEY,—The Murchison Medal has been awarded to Mr. Joseph B. Tyrrell in recognition of the value of his many services to geological science. In the breadth of their scope, in the pioneer element which has so largely entered, in the practical benefits which have often followed, those services may stand as typical of Canada's contribution to Geology.

During more than thirty years Mr. Tyrrell has been frequently engaged in exploring wide tracts of the little-known Barren Lands of Northern Canada, making prolonged journeys of a kind which demands no ordinary resolution and endurance. Besides thus adding largely to geographical knowledge by his own efforts, he has done much to make known the results of earlier explorers in the North. While helping very materially to develop the mineral resources of the Dominion, he has at the same time gathered much valuable information touching the older rocks of the region; and, uniting in his own person the geologist and the prospector, he has often shown by example how science and enterprise may go hand in hand, to the great advantage of both.

On the side of pure science, however, his most notable researches have been in the domain of Glacial Geology, where his extensive acquaintance with the country has enabled him to arrive at conclusions of a large order. Prior to 1894 it was generally held that the ice which once overspread Canada, east of the Cordillera with its mountain glaciers, emanated from a single centre of dispersal. Mr. Tyrrell first demonstrated the existence and approximate limits of a great ice-sheet, which he named the Keewatin, centreing in the country west of Hudson Bay and distinct in origin from the Labradorean ice-sheet on the east. To these two he subsequently added a third, under the name of the Patrician Glacier, which had its gathering-ground to the south of Hudson Bay. His development of this thesis, involving a discussion of the relations in time and space of the ice-sheets radiating from different centres, must rank among the most important contributions to the Glacial history of North America.

In forwarding to Mr. Tyrrell this token of recognition from the Council of the Geological Society, I beg, Sir, that you will add to our congratulations upon what he has already accomplished our hope that many years of activity still remain to him; and this wish will, I am sure, be echoed by his numerous friends on both sides of the Atlantic.

Sir George Perley replied in the following words:—

Mr. PRESIDENT,—I am very happy to come here to-day and receive this Medal on behalf of Mr. Tyrrell, and I only regret that he is not here himself for that purpose. He was in London for some time last year, but unfortunately had to return to Canada last month, so that he has missed the pleasure of being with you to-day. As I live in Ottawa, I have known Mr. Tyrrell for a long time. He is a native-born Canadian, and was for many years connected with the Canadian Geological Survey. He showed much resource and energy in his work, and it is very fitting that he should be recognized by your Society in this way.

I may say that, in our Dominion, we are proud of our Geological Survey and of what it has done. We have a large country with great undeveloped mineral resources, which the Geological Survey has done a great deal to help discover and utilize. Fortunately, Canada has been able to assist more than could have been expected in providing minerals and metals during the War. Many supplies from enemy countries have been cut off, and higher prices have encouraged enterprise. In consequence, we have not only provided large quantities of nickel, but we have developed our

copper, lead, and zinc industries to a very considerable extent. Even so, I feel sure that our mineral and metal products will be greatly increased in the future, and we believe that our resources in that direction have been hardly scratched. To exemplify this, I would remind you that the wonderful silver deposits at Cobalt, in Ontario, we only discovered by chance, although lumbering had been carried on over that district for a great many years. The Ontario Government built a line of railway from the Canadian Pacific into the North country, and in so doing crossed this great silver deposit, which is still producing heavily.

As representing Canada, I am proud to receive this Medal on account of our Dominion, as well as on account of Mr. Tyrrell personally. It seems peculiarly appropriate at this time that this honour should be given by this old and important Society to a Canadian, and we appreciate the same greatly.

I accept the Medal on behalf of Mr. Tyrrell with grateful thanks, and it will give me much pleasure to forward it to him and communicate the very kind words with which you, Mr. President, have accompanied it.

The President then handed the Prestwich Medal, awarded to Professor William Boyd Dawkins, F.R.S., to Dr. A. Smith Woodward, for transmission to the recipient, addressing him as follows:—

Dr. Smith Woodward,—The Prestwich Medal has this year been awarded to Professor W. Boyd Dawkins, and there will appear, I think, a peculiar fitness in the choice which links together these two names. Much of the geological work which here receives recognition is such as would especially appeal to the Founder of this Medal, and did in his life-time engage his lively interest.

During fifty-six years Prof. Dawkins has contributed nearly thirty papers to the Quarterly Journal of this Society, in addition to numerous works published elsewhere. His researches in British cave-deposits and in mammalian palæontology have long been well known and highly valued. He has shown that mammalian remains can be used in the classification of the Tertiary strata, and in many ways has cast light upon some interesting chapters in the later geological history of Europe. In another direction he has made important additions to our knowledge of the geology of the Isle of Man. His long connexion with the Victoria University and the support which he has given to the Manchester Geological Society have done much to promote the study of geology in Lancashire, and his well-known publications *Cave Hunting* and *Early Man in Britain* met the needs of a wide circle of readers.

Even more, perhaps, will the name of Prof. Dawkins be always associated with the discovery of the Kentish Coalfield, in which he guided to a successful issue an enterprise that had already exercised the mind of Prestwich himself. The site of the boring at Dover was selected after a careful survey of the district, and much patient labour was expended on the examination of the cores and the identification by their fossils of the several geological horizons pierced. Apart from the material success realized, there was in this way accumulated a body of information which has important applications to the stratigraphy and tectonics of South-Eastern England.

On behalf of the Council, I ask you to transmit this Medal to Prof. Boyd Dawkins in token that he has indeed, in the words of the Founder, "done well for the advancement of the science of Geology."

Dr. Smith Woodward replied in the following words:—

Mr. President,—I have much pleasure in receiving this Medal on behalf of Prof. Boyd Dawkins, on whom it has been so worthily bestowed. He desires me to express his regret that an unavoidable engagement in Manchester prevents him from being present to-day to return his thanks in person.

He writes :—

"I feel deeply the honour that the Council have conferred upon me. It is specially valuable to me from my long friendship with Prestwich, and because my scientific life has been mainly spent in following up the lines of inquiry which he made his own—the range of the Coal-measures under the Secondary and Tertiary strata of South-Eastern England, the classification of the European Tertiaries, and the problem of the antiquity of man in Britain. With regard to the first, it may be noted that the South-Eastern Coalfield is now clearly defined, and now ranks among the assets of the nation. With regard to the second, the classification by the evolution of the higher mammalia originally intended for Europe is found to apply to the whole of the world. It is now being used by the American geologists (Prof. Osborn and others) to define the complicated subdivisions of the Tertiaries of the New World. With regard to the third, the problem remains now very much as it was in the days of Prestwich, and the zeal of the antiquarians and anthropologists to discover the presence of man in deposits older than the Pleistocene Period has been met by the caution of the geologists, with the net result that the Piltdown remains stand as the oldest in the geological record of Great Britain, and that the alleged occurrence of traces of man in the Pliocene and older strata is put to a suspense account.

"I value, however, the Medal more particularly, as a mark of regard on the part of the Society, to which I have been able to contribute but little for many years, owing to my duties in other directions."

In presenting the Lyell Medal to Henry Woods, M.A., F.R.S., the President addressed him as follows:—

Mr. Woods,—The Council of the Geological Society has selected you for distinction as one who "has deserved well of the Science", and I think that none who has watched your career and is acquainted with your work will dissent from that verdict. Your communication to the Society, in 1896, on the Mollusca of the Chalk Rock, set a standard of skilful and accurate diagnosis and description, which has been maintained in all your subsequent work, including the important monograph on the Cretaceous Lamellibranchia, published by the Palæontographical Society. That the philosophical side of Palæontology has also engaged your study is sufficiently proved by such papers as that on the evolution of the genus *Inoceramus*; while that dealing with the igneous rocks of Builth shows that your interests are not wholly comprised within one branch of our science. Your text-book of Palæontology, based upon practical experience at Cambridge, is valued by other teachers, and your knowledge has always been, as I am well able to testify, generously placed at the disposal of fellow-workers.

It will be, I trust, an encouragement to you, as it is certainly a source of gratification to your friends, that so long a record of good work, faithfully pursued for no private end, does not go unrecognized; and, as an old colleague, I am pleased that it falls to my lot to place the Lyell Medal in your hands as a tangible mark of appreciation.

Mr. Woods replied in the following words:—

Mr. President,—Twenty years ago the Council gave me great encouragement by awarding to me the Lyell Fund. The present award also comes at a time when encouragement is welcome; not that I feel any loss of interest in my work—far from it. But in these times one cannot help regretting, amongst other things, that one's special work in the past has little, if any, bearing on matters which are now of practical importance. It is, therefore, encouraging to find that the Council have taken a longer view, and have continued their traditional policy of giving recognition to any and every branch of Geology, whether it has any obvious practical use or not.

One of the things that struck me most at the beginning of my palæontological work was the generosity and good-nature of those with whom that work brought me into contact, and that pleasant experience has continued all through; whether I have had to do with officials in charge of museums, with professional or amateur geologists, or with that useful person sometimes spoken of disparagingly as the mere collector, all have most freely given me the benefit of their experience and the use of their collections; much as I should like on such an occasion as this to mention their names I must refrain from doing so—the list is far too long, and I regret that it now includes the names of not a few who are no longer living.

Whilst it gives me great pleasure to receive this mark of the Council's approval of my work, it gives me a further pleasure to regard it as a distinction for the Cambridge School of Geology. To those with whom I have been associated in that school I owe much—to some of them I am deeply indebted.

I thank the Council most sincerely for this Medal, and you, Sir, for your kind words.

The President then handed the Balance of the Proceeds of the Wollaston Donation Fund, awarded to Albert Ernest Kitson, to Dr. H. Lapworth, Sec.G.S., for transmission to the recipient, addressing him as follows:—

Dr. Lapworth,—The Balance of the Proceeds of the Wollaston Donation Fund has been awarded to Mr. Albert Ernest Kitson, in recognition of his valuable contributions to Geology in Australia and West Africa.

Beginning in a clerical capacity on the staff of the Department of Mines of Victoria, he qualified himself for scientific investigation, and became ultimately Senior Field Geologist on the Survey of that State. Besides taking an active part in the geological mapping, he wrote numerous papers on the geology of Victoria, and seized opportunities to extend his researches to New South Wales, Tasmania, and New Zealand. In 1906, on the recommendation of his former chief, Prof. J. W. Gregory, Mr. Kitson was placed in charge of the Mineral Survey of Southern Nigeria. With characteristic energy, in a tropical climate, he traversed the Protectorate in every direction, and, in addition to other services, was chiefly responsible for the discovery and investigation of the Udi-Okana Coalfield, containing vast supplies of coal, the more valuable for its geographical situation. This Survey was suspended in 1911, and in 1913 Mr. Kitson received the appointment, which he now holds, of Director of the Geological Survey of the Gold Coast. His reports on that country have not yet been published; but it is perhaps permissible to mention the discovery of fossiliferous Palæozoic rocks of considerable geological interest, and of deposits of manganese-ore and of bauxite which have great economic importance.

That so notable a record of good work should receive recognition from this Society must gratify all who are interested either in the advancement of geological knowledge or in the mineral resources of the British Empire.

In presenting the Balance of the Proceeds of the Murchison Geological Fund to Thomas Crook, Assoc.R.Coll.Sci., the President addressed him as follows:—

Mr. Crook,—In awarding to you the Balance of the Proceeds of the Murchison Geological Fund the Council wishes to recognize the value of your contributions to Petrology and Mineralogy, more particularly with reference to the mechanical analysis of rocks and also to the mineralogy of the British Colonies. The former of these subjects engaged your attention while you were at the Royal College of Science in Dublin, and you have since pursued it with success, especially in perfecting the use of the electro-magnet for the separation of minerals. As a member of the staff of the Imperial Institute you have during recent years made many additions

to our knowledge of the minerals of the more remote parts of the British Empire, the results of your work appearing partly in papers published in your own name, but largely in the pages of the Bulletin of the Institute. Your petrological publications include some interesting observations on "Dedolomitization" and a suggestive paper on "The Genetic Classification of Rocks and Ore-Deposits". In addition, you have collaborated with Prof. Cole in an important memoir on a collection of rock-specimens dredged off the coast of Ireland, showing how these may be made to yield information concerning the submarine geology of the British seas. This award, so well deserved, will, I hope, be an encouragement to you in your future work, whether official or extra-official.

The President then presented a moiety of the Balance of the Proceeds of the Lyell Geological Fund to Vincent Charles Illing, M.A., addressing him as follows:—

Mr. Illing,—The Council has awarded to you one moiety of the Balance of the Proceeds of the Lyell Geological Fund to mark its appreciation of your admirable work among the Lower Palæozoic rocks of Warwickshire. Since its discovery by Prof. Charles Lapworth in 1882, the Cambrian inlier of Nuneaton has claimed the attention of numerous geologists; but it was reserved for you to show how complete a development of the whole Cambrian succession is there exhibited. In a paper communicated to this Society in 1914 you mapped out the various subdivisions which you had recognized, and correlated them with the parallel sequence in other areas. Of the Abbey Shales, representing in small compass a large portion of the Middle Cambrian, you made a full palæontological study, describing critically the rich trilobitic fauna and making known a number of new species. That this important memoir was professedly only a first instalment, warrants us in hoping that you will find in the present award stimulus to the completion of your projected work.

In presenting the other moiety of the Balance of the Proceeds of the Lyell Geological Fund to William Kingdon Spencer, M.A., the President addressed him in the following words:—

Mr. Spencer,—A moiety of the Balance of the Proceeds of the Lyell Geological Fund has been awarded to you by the Council as an acknowledgment of the value of your palæontological work.

Starting with the advantage of a zoological training at Oxford, you have devoted the intervals of a busy official life to researches in the palæontology of the Echinoderms. You began by applying Prof. Sollas's method of serial sections to elucidate the structure of the Palæozoic forms *Palæodiscus* and *Agelacrinus*. You then devoted some years to the study of the Cretaceous star-fishes, the results of which appeared in a monograph upon the British examples and a paper, contributed to the Royal Society, upon "The Evolution of the Cretaceous Asteroidea". Therein you showed, among other conclusions, that the star-fishes are of zonal importance, and that different lineages were evolved along parallel lines. More recently you have been investigating with great skill that difficult group of fossils, the Palæozoic Asterozoa, and your monograph, not yet completed, has already brought to light many new facts relative to the morphology and phylogeny of those early Echinoderms. It is our hope that this recognition may encourage you to persevere in the same path.

The President then delivered his Anniversary Address, giving first obituary notices of H. Émile Sauvage (elected Foreign Correspondent 1879), W. Bullock Clark (For. Corr. 1904), T. McKenny Hughes (el. 1862), Edward Hull (1855), R. H. Tiddeman (1869), G. A. Lebour (1870), Arnold Hague (1880), Robert Bell (1865), G. F. Franks (1890), G. C. Crick (1881), H. P. Woodward (1883),

Upfield Green (1889), C. O. Trechmann (1882), A. N. Leeds (1893), R. Boyle (1911), A. M. Finlayson (1909), and others.

The President went on to discuss the present position and outlook of the study of metamorphism. The rapid development of physical chemistry and the successful application of experimental methods to petrological questions have greatly changed the situation during recent years, and for the first time it seems possible to approach the subject of metamorphism systematically from the genetic standpoint. For the geologist this implies the critical study, not only of the great tracts of crystalline schists and gneisses, but equally of metamorphic aureoles, of pneumatolysis and other contact-effects, and of the phenomena, mechanical and mineralogical, related to faults and overthrusts. It implies, moreover, the recognition that these are all parts of one general problem, that of the reconstruction of rocks under varying conditions of temperature and stress. In practice, this problem is complicated by the fact that perfect adjustment of chemical equilibrium cannot be assumed, either in the rocks prior to metamorphism, or during the process of metamorphism itself.

Some consideration was devoted to the solvents which play an essential part in metamorphism and to the limits of migration of dissolved material within a rock-mass. The Address proceeded to the discussion of what is the most fundamental characteristic of metamorphism: namely, that recrystallization takes place in a solid environment, and so may be profoundly affected by the existence of shearing stress. Stress of this type, on the one hand, arises from the crystal growth itself, and on the other hand is called into play by external forces. The automatic adjustment of the internally created stress to neutralize that provoked from without affords the key to all structures of the nature of foliation. The mineralogical peculiarities characteristic of the crystalline schists must find their explanation in kindred considerations; for it can be shown that the chemistry of bodies under shearing stress differs in important respects from the chemistry of unstressed bodies. The result is seen in the appearance of a certain class of "stress-minerals" where the dynamic element has figured largely in metamorphism, while in the same circumstances the formation of minerals of another class seems to have been inhibited. But, while some of the general principles governing the effects can be formulated, the explanation of these lines of the observed associations of minerals is a task for the future. It may be that many of the particular problems involved will in time be brought within the scope of laboratory experiment.

The conditions governing metamorphism are temperature and shearing stress, with uniform pressure as a factor of less general importance. If the orogenic forces are sufficient to maintain shearing stress everywhere at its maximum, the stress itself becomes a function of temperature, since this determines the elastic limit, and the principal conditions of metamorphism come to depend upon a single variable. This degree of simplification, however, is not to be expected universally. One disturbing factor is the local rise of temperature sometimes caused by the mechanical generation of heat in the crushing of rock-masses.

In resigning the chair, the President expressed his thanks to the Fellows of the Society, and especially to the Officers, who, as well as the permanent officials, had contributed much to the smooth working of the Society's business.

The ballot for the Officers and Council was taken, and the following were declared duly elected for the ensuing year :—

Officers (who are also *ex-officio* members of the Council): *President:* George William Lamplugh, F.R.S. *Vice-Presidents:* R. Mountford Deeley, M.Inst.C.E. ; Alfred Harker, M.A., LL.D., F.R.S. ; Professor William Johnson Sollas, M.A., LL.D., Sc.D., F.R.S. ; and Sir Jethro J. H. Teall, M.A., LL.D., D.Sc., F.R.S. *Secretaries:* Herbert Henry Thomas, M.A., Sc.D. ; and Herbert Lapworth, D.Sc., M.Inst.C.E. *Foreign Secretary:* Sir Archibald Geikie, O.M., K.C.B., D.C.L., LL.D., Sc.D., F.R.S. *Treasurer:* James Vincent Elsden, D.Sc.

Council : Charles William Andrews, D.Sc., F.R.S. ; Francis Arthur Bather, M.A., D.Sc., F.R.S. ; Professor John Cadman, C.M.G., D.Sc., M.Inst.C.E. ; Arthur Morley Davies, D.Sc., A.R.C.Sc. ; Professor Edmund Johnston Garwood, M.A., Sc.D., F.R.S. ; John Frederick Norman Green, B.A. ; Finlay Lorimer Kitchen, M.A., Ph.D. ; Major Henry George Lyons, D.Sc., F.R.S. ; Professor John Edward Marr, M.A., Sc.D., F.R.S. ; Richard Dixon Oldham, F.R.S. ; Robert Heron Rastall, M.A. ; Professor Henry Hurd Swinnerton, D.Sc. ; Samuel Hazzledine Warren ; Professor William Whitehead Watts, M.A., Sc.D., LL.D., F.R.S.

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2. *March* 6, 1918.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

Mr. J. F. N. Green delivered a lecture on the Igneous Rocks of the Lake District. He first drew attention to some of the manuscript 6 in. maps of the Lake District, prepared nearly fifty years ago, by the Geological Survey, and pointed out that, although undoubtedly most accurate, they differed greatly in the volcanic area from his own. He suggested that the reason was that there was a fundamental difference in the classification of tuffs and lavas. A large proportion of the Lake District rocks were brecciated, and had been supposed to be altered tuffs. With the unbrecciated rocks into which they passed they had been mapped as ashes. A number of specimens and photographs were shown, indicating that the brecciation and apparent bedding were due to flow. Specimens were also shown of explosion breccias, of the normal tuffs (which the Lecturer believed to be mainly the result of erosion between eruptions), and of rocks simulating true tuffs, but actually sandstones and conglomerates, composed of detrital igneous material. Attention was drawn to the criteria for distinguishing the various types. Recently manuscripts had been found in the possession of the Geological Survey proving that Aveline, whose maps were extraordinarily accurate and detailed, had anticipated by thirty years the Lecturer's separation from the volcanic rocks of the basal beds of the Coniston Limestone Series.

When re-mapped on this basis, the Borrowdale Series appeared as a simple and regular sequence, strongly folded and cropping out in long bands. An interesting history of vulcanicity was revealed, beginning in many places with explosion tuffs followed by a great series of pyroxene-andesites over the whole district. Then there

was a pause during which fine-grained andesite tuffs, with a tendency to produce true slates, accumulated. This was succeeded by a vast outpouring of andesites, of great thickness in the central mountain region, but dying out southwards and eastwards. Next a series of peculiar mixed tuffs, of special value in mapping, was covered by another mass of andesites dying out south-westwards. After this, soda-rhyolites covered the whole district, nothing later being preserved—with one possible known exception. These volcanic rocks were intersected by a varied series of intrusions.

The solfataric phenomena were of interest, including the production of garnet and graphite, and a remarkable "streaky" structure in the rhyolites.

An important question related to the age of the large acid intrusions associated with the volcanic rocks. Were they of the same age as, or later than, the Devonian folding? A sketch was given of the evidence on which the Lecturer assigned the Eskdale and Skiddaw granites to the Ordovician volcanic episode, and it was suggested that the great Skiddaw anticline was not due to regional folding, but a local structure connected with the vulcanicity.

Lantern-slides of Lake District country were shown, and the manner in which the volcanic rocks entered into the scenery was pointed out.

II.—Edinburgh Geological Society.

February 20, 1918.—Professor Jehu, President, in the Chair.
(Issued March 16, 1918.)

1. "Coal Apples." By J. Masterton, H.M.I.M.

At the Lochend Pit of Longrigg Colliery, Longriggend, in the Upper Drumgray Seam, which is there anthracitic, Mr. Masterton found in 1910 rounded balls of coal from 1½ inches to 5 inches diameter, and occasionally up to 8 inches diameter. The balls were slickensided, and, when seen in situ, the surrounding coal matter was sometimes slightly displaced. The larger balls, when broken, had a strong likeness to cone-in-cone coal. The late Dr. Clough was shown the balls, and he drew attention to a note in the Transactions of the Glasgow Geological Society recording the discovery of similar balls in North Ayrshire by Mr. John Smith. Mr. Smith found the balls near a whin float.

The apples in Lochend Pit occur in an anthracitic coal, and Mr. Masterton found similar balls in most of the pits near Lochend, both in the Upper and Lower Drumgray Seams. The whin float which underlies the Slamannan District has been proved by bores, and is seen at the surface near Forrestfield, to the south of the Lochend Pit; it has almost certainly both anthracitized the coal and formed the apples, and Mr. Masterton cannot accept Mr. Carruthers' assertions in the Geological Survey's publications as to the formation of the anthracites in the area in question by agencies similar to those to which the anthracitization of the coals of South Wales has been ascribed.

Specimens were exhibited from Lochend Pit (Upper Drumgray Seam), Drumbon Pit (Upper and Lower Drumgray Seams), and from Eastfield Pit (Upper and Lower Drumgray Seams).

Coal apples were found by Mr. Masterton during the years 1911 to 1913, and he exhibited specimens from the following localities: (1) Moncur Colliery, Kilwinning—in the Ell Seam in a reversed fault, and where a line of face was slightly baked and approaching a whin dyke; (2) Littlemill Colliery, Rankinston—Main Seam, where the working face was approaching a whin dyke; (3) Earallan Colliery, Old Cumnock—Maid Splint Seam, in a place going parallel to a whin dyke, and 25 yards distant from it; (4) Ponfeigh Colliery, Douglas, Lanarkshire—apples described by the manager as occurring near a whin dyke, the coal becoming coke close to the dyke.

Mr. Masterton advanced the opinion that the coal apples were pieces of coal matter either of harder nature or of less volatile content than the surrounding parts of the seam, and that these parts resisted the compression and "flux", if the term can be used, better than the rest of the seam.

2. "The Raw Materials of the Glass Industry." (With lantern illustrations.) By G. V. Wilson, B.Sc., F.G.S.

A brief description was given of the materials needed for the manufacture of glass, with special reference to the quality of sand used. The essentials of an ideal sand were pointed out, namely, high percentage of silica, freedom from ferruginous materials, and absence of refractory minerals, such as rutile and zircon. Attention was drawn also to the importance of the size and shape of the grains. Analyses of Fontainebleau and Dutch sands were compared with those from the best Scottish localities. None of the latter are quite equal to Fontainebleau, but several are as good as, if not better than, Dutch. The essential qualities of the clay for making glass pots were also noted, such as high plasticity, high refractory quality, and freedom from iron in any form. The paper was illustrated by lantern slides, many of which were photomicrographs showing the minerals formed by the devitrification of a large body of glass.

OBITUARY.

CAPTAIN LEWIS MOYSEY, R.A.M.C., B.A., M.B., F.G.S.

BORN 1869. DIED FEBRUARY 26, 1918.

WE much regret to learn of the death of Dr. Moysey, who was lost on the hospital ship *Glenart Castle*, which was torpedoed on February 26. Dr. Moysey had only just joined this ship, as one of the medical officers, and he was not among those subsequently rescued.

Dr. Moysey was a graduate of Caius College, Cambridge, and a medical man who had long been in practice at Nottingham. He was mobilized in the early days of the War, and until quite recently he had been occupied with regimental work in this country.

He had devoted, over a period of many years, the scanty leisure of a busy professional life to the collection of the fossil remains of the Coal-measures around his home at Nottingham. He was an exceptionally ardent palæontologist, with a keen eye for a good specimen, and he was possessed of great skill and perseverance as a collector.

He rediscovered a half-forgotten method of developing fossils contained in clay-ironstone nodules, by freezing them in cold storage. This he described in a paper in the GEOLOGICAL MAGAZINE for 1908.

He also contributed several memoirs on some of the rarer specimens in his collection. Among these may be mentioned his writings on *Palæoxyris* and allied genera, published by the Geological Society in 1910 and the British Association in 1913 (1914), which did much to clear up the obscurities which then surrounded these fossils. But, as a rule, he was content, with great generosity, to place the results of his labours in the field in the hands of specialists for description.

His collection covered a wide range both of Coal-measure animals and plants, not a few being unique or exceptionally perfect examples. Some of the former have been described in the pages of the GEOLOGICAL MAGAZINE, by Dr. Henry Woodward in 1907 and 1908 and Dr. W. T. Calman in 1914, and in the publications of the Palæontographical Society by Mr. R. I. Pocock in 1911.

Dr. Arber some years ago (1910) also figured some of the best of the plant remains in his collection, but many further examples which Dr. Moysey had since acquired remain undescribed. It is not too much to say that our exceptionally good knowledge of the fauna and flora of the Notts and Derby Coalfield is due almost entirely to his single-handed efforts, as his list of records contained in the recent Survey memoir dealing with this field testifies.

A few weeks before his death, as if conscious of his impending fate, Dr. Moysey made over as gifts his entire collections, the animal remains to the Museum of Practical Geology in London and the plant specimens to the University of Cambridge. The latter are now in the Sedgwick Museum.

Dr. Moysey possessed many friends among those interested in Coal-measure fossils, and his delightful personality, generous nature, and enthusiasm for research had endeared him to all of them.

[NOTE BY THE EDITOR.—Of the Arthropods discovered by Dr. L. Moysey the first specimens were sent in May, 1907, to his friend Mr. Henry A Allen, F.G.S., of the Geological Survey, Jermyn Street, and described by Dr. Henry Woodward in the GEOLOGICAL MAGAZINE for June, 1907 (pp. 277–82, Plate XIII). They consisted of examples of *Eurypterus* (*E. Moyseyi* and *E. Derbiensis*) from the clay-ironstone nodules of the Coal-measures, Ilkeston, Derbyshire.

As the result of his experiments in splitting by a freezing and thawing process the ironstone nodules obtained on the Shipley Hall Estate clay-pit, near Ilkeston, Dr. Moysey records the fortunate discovery of a greater proportion of rare fossils in these harder

nodules than from those found naturally inclined to split in the clay-pit. Out of some ninety nodules cracked by freezing he had obtained three specimens of *Belinurus*, one of *Palæoxyris*, two of a "*new shrimp-like animal*", and one complete but diminutive example possibly akin to *Arthropleura armata* of Jordan from Saarbrucken—he enumerated fifty-seven different fossil organisms obtained (see Geol. Mag., 1908, pp. 220–2).

The new shrimp-like animal (*Præanaspides præcursor*, H. Woodw.) referred to by Dr. Moysey, and discovered by him, proved to be of the very highest interest, being a Coal-measure representative, or ancestral form, of the rare modern Schizopod *Anaspides tasmaniæ* from Mt. Wellington, Tasmania (see H. Woodward, Geol. Mag., 1908, pp. 385–96).

On March 23, 1910, Dr. Moysey read a paper before the Geological Society of London on *Palæoxyris* and other allied fossils from the Derby and Nottingham Coal-field (see Quart. Journ. Geol. Soc., vol. lxvi, pp. 329–44, pls. xxiv–vii, 1910).

Dr. Moysey contributed a note on some undescribed Coal-measure fossils from the Nottinghamshire coal-field (British Association, Sheffield, 1910, Sect. C, see also Geol. Mag., 1910, p. 474).

In 1911 Mr. R. I. Pocock, F.R.S., contributed a "Monograph of the Terrestrial Carboniferous Arachnida of Great Britain" to the annual volume of the Palæontographical Society for 1910, in which two species obtained by Dr. L. Moysey are figured and described, namely: *Eobuthus holti*, sp. nov. (see p. 15, pl. ii, fig. 2*a*) and *Geralinura britannica*, sp. nov. (p. 30, pl. ii, fig. 3).

In the Geological Magazine for 1911, pp. 497–507, twelve Text-figures, Dr. Moysey described a further series of fossils from the Notts and Derbyshire Coal-field, including a new bivalved Entomostracan, *Leaia trigonioides*, sp. nov. (Fig. 1, p. 498), parts of an undescribed Arthropod, and remains of *Prestwichia* (?), of a Scorpion, of *Eurypterus*, carapace of *Anthracosiro* sp., of *A. Fritschii*, Pocock (Figs. 7, 8, p. 503, and Fig. 9, p. 504), of *A. Woodwardi*, Pocock (Fig. 10, p. 504), an opisthoma of *Anthracomartus* (Figs. 11, 12, p. 505); he appends a list of sixteen Arthropods and six other fossil remains.

At the Meeting of the British Association, Birmingham, 1913, Dr. Moysey read a paper on *Palæoxyris* and other allied fossils and on *Vetacapsula* (see Geol. Mag., 1913, pp. 453–5). The author compares these problematical bodies from the Coal-measures with the egg-cases of *Chimæra collei*, *Rhinochimæra*, and other Chimæroid sharks.

In 1914 (Geol. Mag., pp. 541–4, Pl. XXXVIII) Dr. W. T. Calman figures and briefly describes a remarkable new form of "Myriopod-like" Arthropod probably related to *Arthropleura armata* of Jordan, from the Coal-measures of Saarbrucken, of which similar fragmentary remains have been obtained from other coal-fields of France and in this country. Dr. Calman considers it to be a new species of Arthropod (*incertæ sedis*), and names it *Arthropleura Moyseyi* after the discoverer, Dr. L. Moysey.

The Council of the Geological Society of London so lately as